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Stem Rust of Wheat and its Control by Breeding Resistant Varieties.

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INTRODUCTION.

During the 1943 season, stem rust of wheat assumed epidemic proportions in many parts of Western Australia, the outbreak being the most serious experienced here since 1934. The disease became general throughout the north-eastern wheat belt, and it also caused severe damage in many other places, including the Northampton area in the northern wheat belt; and the Borden area in the Great Southern.

At this stage it is impossible to make an accurate estimate of the losses suffered, but judging by reports from farmers crops of some varieties were completely ruined, while reduction in yield of from 25-75 per cent. was common. Also in many cases crops were cut for hay instead of being harvested for grain. Fortunately stem rust in serious form occurs less frequently here than in many other places, as climatic conditions, which have an important bearing on its occurrence, are seldom ideal for its full development.

Nevertheless severe damage has at times been caused and it has been estimated that the 1934 epidemic cost wheat growers approximately £200,000.

In the north-eastern wheat belt many farmers had never experienced rust prior to the 1943 outbreak and were thus unaware of the nature of the disease. On the other hand, from older districts where losses have occurred before, numerous enquiries have been made concerning resistant varieties suitable for local conditions which it is known the Agricultural Department has been endeavouring to produce for some years.

In this article, therefore, the nature of wheat stem rust is described with especial reference to the work which is being carried out locally to obtain resistant varieties by plant breeding methods.

BREEDING RUST-ESCAPING VARIETIES.

The wheats available to the pioneer Australian settlers were late maturing English and South African varieties. Because of their long growing season, they could be successfully cultivated only in the wetter districts where, however, they were subject to almost annual rust epidemics or tip-withering. By the 70's

of last century the future of the wheat industry appeared to be very insecure, as it was becoming increasingly profitable to use these areas for other crops.

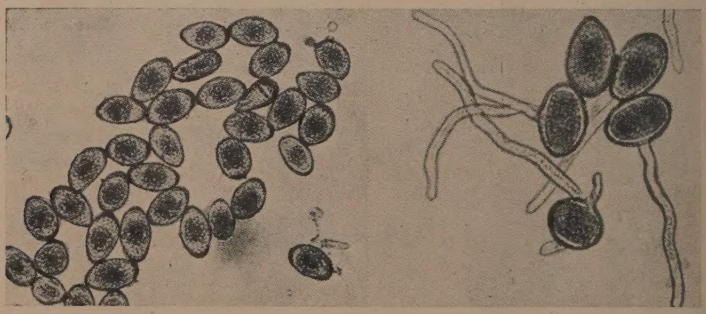
Two varieties selected in South Australia afforded some relief. In 1881, Dr. Schomburgh of the Adelaide Botanic Gardens, forwarded a small parcel of a South African wheat to the chairman of a South Australian Farmers' Association, requesting him to distribute it among the members. These included James Ward of Nelshaby, Port Pirie, who obtained a handful and planted it in his garden. At harvest time the plot was "as rusty as a horsenail" with the exception of a few plants, the seed of which was distributed as Wards Prolific. From this variety H. J. Gluyas of Port Germein, South Australia, selected Gluyas Early, which possessed some resistance to rust at that time.

The earliest attempt to breed new varieties by cross-pollination was made by William James Farrer in New South Wales towards the close of the last century, and the varieties he produced, particularly Federation, were a very marked improvement on those previously in cultivation. Farrer recognised that varieties differed in their resistance to stem rust, and one of his principal aims was to breed a rust resistant variety. That he was not very successful in this direction is not surprising, for at that time no varieties of bread wheat were known which possessed more than very moderate rust resistance. However, he largely achieved the same result by breeding earlier maturing wheats which tended to be rust escaping, and these subsequently played a big part in the expansion of the Australian Wheat Belt for although susceptible to rust they were not as seriously damaged as later maturing varieties.

CAUSE AND SYMPTOMS OF STEM RUST.

Stem rust of wheat is caused by the attacks of a fungus, *Puccinia graminis tritici*. Fungi are primitive plants which under natural conditions depend on plant or animal matter, either living or dead, for their food. The fungus causing stem rust of wheat, in common with the other numerous rust fungi, is a *strict* parasite, that is to say, it can only draw nourishment from the living cells and grow at the expense of the plant it attacks.

Generally the disease is first noticed in spring when it becomes obvious by the development of elongated reddish spots or pustules, mainly on leaf sheaths and stems, but to some extent on the leaves also. The pustules contain a rusty looking powdery mass from which the disease derives its name.



a. b.

Figure 1.

(a) Red spores (uredospores) of wheat stem rust; x 230. (b) Germinating red spores. The thread-like outgrowths are germ-tubes which enter the breathing pores of wheat and other susceptible plants thereby causing infection; x 300.

(After Craigie.)

When viewed under the microscope this powder is seen to consist of countless oval reddish-brown bodies each about one-thousandth of an inch in diameter (figure 1a). These are the spores (uredospores) of the fungus by means of which the disease is rapidly spread under favourable conditions. Fungal spores are reproductive bodies with the function of seeds, and they are capable of giving rise to new individuals. As we shall see, several kinds of spores may be produced by the same fungus. The uredospores are carried about by wind and some eventually lodge on other wheat plants. If the plant surfaces are dry, infection cannot take place, but if they are moist either from rain or dew the uredospore germinates within an hour or two and sends out a thread-like filament or germ-tube (figure 1b) which enters the host plant through one of its breathing pores. Within the breathing pore the germ-tube soon commences to branch out between the living plant cells from which food is absorbed by means of sucker-like organs (haustoria), which pierce the cell walls (figure 2). As the rust fungus derives nourishment

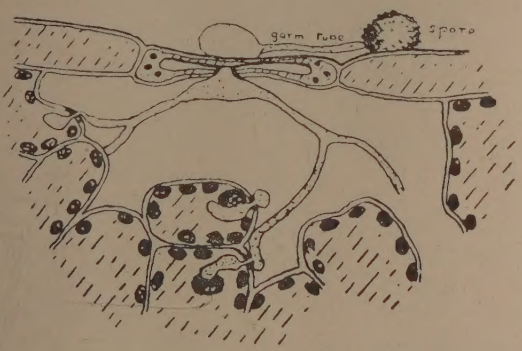


Figure 2.
Stem rust of wheat. Infection of leaf by uredospore through a breathing pore.
(After Osborne.)

and develops at the expense of the plant attacked, the latter is usually referred to as the host plant. After growing in the host for about five to ten days (the exact time depending on a number of conditions) the fungus commences to form a new generation of uredospores. These develop just beneath the surface layer or epidermis of the plant, and as they grow and mature the epidermis is finally burst open exposing to view the reddish spores in the typical elongated rust pustule.

New uredospores may continue to form and be distributed from the opened pustule as long as the plant remains green, and resulting from the infection of a single uredospore, several hundred similar spores may be produced in the next generation. With favourable weather conditions this process of infection and new pustule production steadily increases as the season advances, until the pustules are so numerous that the vigour of the crop declines. The result is a more or less complete crop failure.

As the affected plants commence to dry off a remarkable change takes place, the red pustules being replaced by black ones (figure 3). This second stage is often called "black" or "summer" rust, and it is caused by the production of dark brown or black spores of another kind, teleutospores. These spores are known as resting spores, as their function is to perpetuate the fungus after the death of the host plant until the following season (figure 4a).

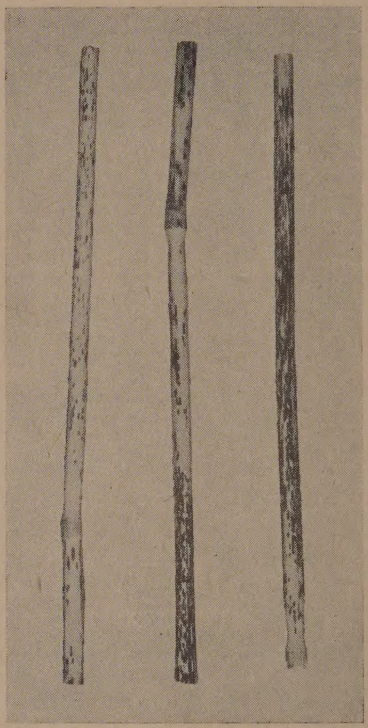
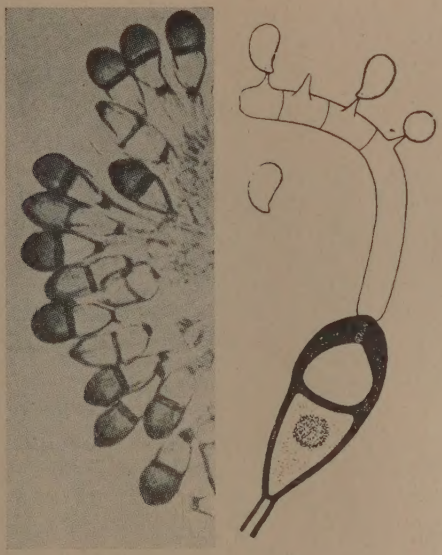


Figure 3.
Portions of wheat stems showing rust pustules in the black stage.

After exposure to cold during the following winter months on infected crop residues, the resting spores germinate in late winter or spring to produce four secondary spores, sporidia (figure 4b). These, quite unlike the uredospores, cannot infect wheat plants or certain grasses, but only a few species of an entirely different plant, the barberry, and chiefly the common barberry, *Berberis vulgaris*. On this alternate host plant the stem rust fungus completes the third and final stage in its life cycle with the production of another kind of spore. These are known as aecidiospores, and they are produced in special structures called clustercups (figure 5). The aecidiospores cannot attack the barberry, but only wheat or other susceptible plants. Fortunately, as far as is known, susceptible barberry plants do not occur in Western Australia or in Australia generally. Largely for this reason, therefore, the black resting spores of stem rust do not fulfil their natural function and give rise to barberry infections under Australian conditions.

That they retain their capacity to do so, however, has been proved by Dr. W. L. Waterhouse of Sydney University. Under controlled conditions Dr. Waterhouse has often produced experimentally the characteristic clustercups on barberry plants by means of resting spores from wheat which has previously been exposed to extremely cold winter weather.



a. b.

Figure 4.
(a) Black resting spores (teleutospores) of wheat stem rust; x 240. (b) Drawing to represent the germination of a black resting spore. Note the four secondary spores (sporidia).
(After Craigie.)

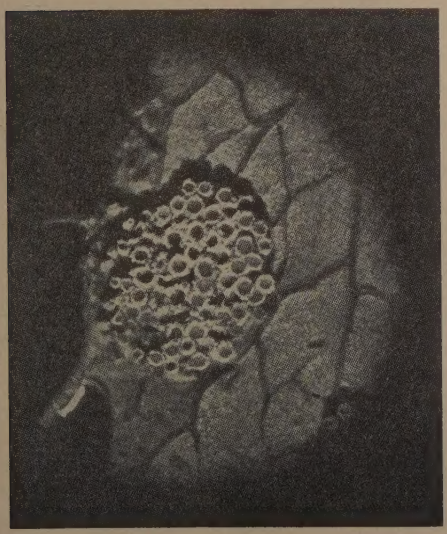


Figure 5.
Clustercups of stem rust on the under side of a barberry leaf. x 8.
(After Bailey.)

Also, in 1933, the clustercup stage of wheat stem rust was found naturally occurring on a common barberry growing in a private garden at Yetholme, New South Wales. Following on this discovery a proclamation was issued by the New South Wales Government in 1935 enforcing the eradication of this shrub, and prohibiting its further sale. The importance of this step to the wheat grower will be shown later.

RACES OF WHEAT STEM RUST.

The fungus causing wheat stem rust, *Puccinia graminis tritici*, cannot be regarded as a single entity, for it comprises a number of different races. These races are identical in appearance, but their capacity to attack different varieties of wheat varies considerably. Thus a variety of wheat highly resistant to one race of the fungus may be very susceptible to another, and furthermore, as the distribution of the races is not uniform, the resistance which a variety shows in one state or country may break down completely when the variety is introduced elsewhere.

It follows, therefore, that before the breeding of rust resistant varieties of wheat can be undertaken with any certainty of success, a knowledge of the races of rust present, at least in the localities where they are to be grown, is imperative.

Physiologic specialisation of this kind is not confined to the organism causing wheat stem rust. It is found in many other different rusts, including the closely related stem rusts of oats and rye, in the powdery mildews, and numerous other organisms.

The discovery of physiologic specialisation in the cereal rusts was first investigated by Eriksson about fifty years ago and this phenomenon has profoundly influenced the work of breeding for disease resistance.

Dr. E. C. Stakman of Minnesota, U.S.A., has been largely responsible for evolving methods for identifying different races by the types of infection each race produces on seedlings of a given set of cereal varieties. Each race, when identified, is assigned a number, and more than 150 races of wheat stem rust have now been distinguished in various parts of the world.

To separate races of wheat stem rust twelve different standard wheat varieties, generally called differential varieties, are used. Each rust is grown on seedlings of these varieties, and the types of infection produced by a given race on each variety of the differential set are recorded, and represented, by symbols which indicate the degrees of susceptibility or resistance.

Types of infection are shown in Figure 6 and they vary from whitish hypersensitive flecks with no evidence of red pustules, to large pustules containing an abundance of spores.

The flecks of the highly resistant "0;" type indicate that infections occurred, and killed small groups of cells at several points; but being a strict parasite, the fungus cannot absorb food from the dead plant cells and thus it is unable to establish itself, and produce spores. In the highly susceptible "4" type however, the plant cells are not killed by the fungus, so the latter can develop and produce spores abundantly (see also page 10).

It has been found that at least on one, and often on two or more of these differential varieties, the infection types produced by any two races differ distinctly, whereas similar races show the same reactions. For example, on the differential variety Mindum, race 34 produces the highly susceptible "4" type of infection, but race 43 on this variety shows the "0;" type of high resistance. Similarly any

other two races show different infection types on at least one of the differential varieties. Thus, by comparing the infection types of an unknown rust with those previously recorded locally and elsewhere it can be identified as either a new or known race.

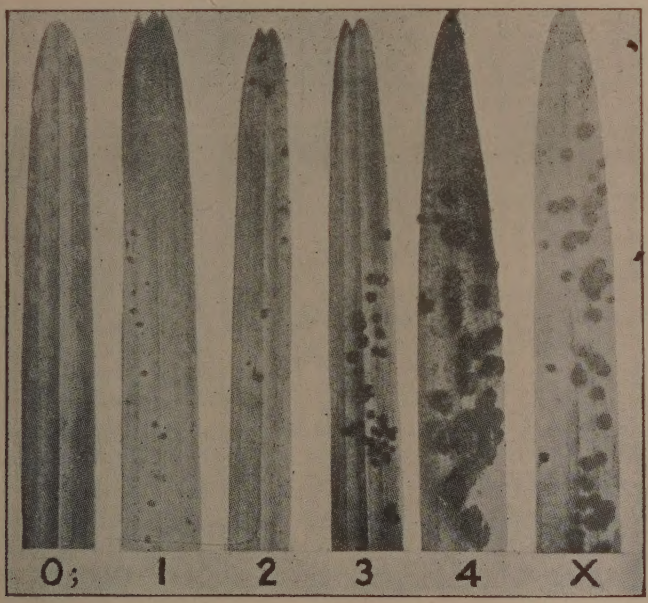


Fig. 6.
Infection types and the symbols by which they are represented. The "0;" type on the left indicates very high resistance. Note the hypersensitive flecks. The next four types ("1", "2", "3" and "4") indicate increasing susceptibility. The "X" type indicates an indeterminate reaction representing a mixture of infection types on the one leaf.
(Modified after Waterhouse.)

Work of this kind has been carried out in various countries, under carefully standardised environmental conditions in the glass house.

Careful standardisation is essential if comparable results are to be obtained by scattered workers, for environmental conditions, especially temperature, and light intensity, may alter the reactions of certain of the differential varieties.

In Australia, the determinative work is carried out by Dr. W. L. Waterhouse of Sydney University from rust collections forwarded from the various States, and to him, more than to any other worker, are we indebted for our knowledge of the biology and nature of the Australian rust flora. Up to the present he has identified 10 races in Australia, but only two of these, races 34 and 43, occur in W.A.

It is important to emphasise again that in breeding resistant varieties of wheat the plant breeder is not merely concerned with a single fungus causing wheat stem rust, but rather with the several races of the fungus to which his varieties will subsequently be exposed.

Origin of Races.

New races may arise in two main ways, as a result of barberry infections and by mutation. In 1865 it was shown for the first time, by De Bary, that the barberry is the alternate host of the stem rust fungus on which the third stage of its life-cycle is completed. Long before this, however, farmers in England, North America, and Northern Europe had realised that there was some mysterious connection between the occurrence of barberries in their fields and outbreaks of stem rust, and from about the middle of the eighteenth century onward various countries where the barberry existed enacted legislation for its eradication.

However, the importance of the barberry in relation to the occurrence of stem rust only became fully evident in 1927. In that year J. H. Craigie of the Dominion Rust Research Laboratory, Winnipeg, Canada, discovered that during its development on the barberry the stem rust fungus passes through a sexual phase as a result of which entirely new races may be evolved.

Under glasshouse conditions, Craigie showed that when barberries are infected with two races, crossing may occur and from such crosses more than fifty new races were produced, most of which had never been found in the field.

Also in the glasshouse Dr. Waterhouse has shown that barberries infected with the hybrid race 34, which is widespread in Australia, give rise to other races, including 11 and 56. Now race 11 was first found in the field in 1935 near Yetholme, in New South Wales, the locality where barberries naturally infected with race 34 were discovered in 1933. Its occurrence there can thus be traced to the infected barberries at Yetholme.

On the other hand, race 56 has not yet been reported from the field in Australia, but in the United States of America it is one of the most virulent races. Its advent there has meant that the once popular and hitherto resistant variety Ceres has now almost passed out of cultivation, because of its susceptibility to race 56; and in consequence other wheats with higher resistance have had to be bred.

Clearly then barberries may multiply the races of stem rust and seriously complicate, if not nullify, the work of plant breeders. Thus we are extremely fortunate in Australia that barberries do not occur here as regular alternate hosts of the stem rust fungus, for as mentioned previously, climatic conditions will permit of barberry infections at least in some localities.

In addition to arising from barberries, new races may also be evolved by mutation. Mutations are known to occur but they may be very difficult to detect unless the mutant differs markedly from the parent race in the varieties it can attack.

Recently a new race (biotype) has occurred in New South Wales which shows, as Dr. Waterhouse has demonstrated, all the reactions of race 34 when tested on seedlings of the differential set of varieties in the plant house. That it is not identical, however, is obvious, for the variety Eureka is susceptible to it, whereas this variety is resistant to the standard race 34.

Similarly, from rust collections of race 34 made in W.A., Dr. Waterhouse has detected in some lots minor variations, but fortunately these are of no greater consequence from the plant breeders' standpoint than the parent race.

In the general absence of the barberry, therefore, it is difficult to account for such occurrences except on the basis of mutation.

Changes in Race Distribution.

Following the occurrence of a new race, changes in the distribution and prevalence of existing races may take place quickly.

Until 1925 only six races of wheat stem rust were known in Australia, and only one of these, race 43, occurred in Western Australia.

In November, 1925, however, a new race appeared in this State which was subsequently identified as race 34. It was recorded again from New South Wales in 1926 and by 1929 it had superseded the other races in all States. Since then it has remained the most widely distributed of all the Australian races of wheat stem rust. In the absence of the barberry, the origin of race 34 in Western Australia can only be surmised; it is not improbable, however, that it arrived from some other country in air currents. Fungal spores, including the uredospores of rust, are known to be transported great distances by wind, and they have also been trapped from aeroplanes at high altitudes.

The ability of a new rust race to spread in the field in competition with other races, depends to a large extent on the prevalence of varieties which it can attack. If it can attack more of the widely grown varieties than the remaining races, opportunity for its spread is obviously much greater than when the converse is the case. Race 34 can attack many of the most popular varieties, and so its spread is not restricted, but these same varieties are resistant to some at least of the remaining races, which are therefore limited in their dispersal.

Race 34 is also more virulent than the other Australian races of wheat stem rust. When this race infects a susceptible variety with its uredospores it produces a new generation of similar spores more rapidly than do the remainder. Thus, when the period of weather favourable to the development and spread of rust is limited, this race has an obvious advantage compared with the others.

As mentioned previously, a new race of rust capable of attacking the hitherto resistant Eureka variety has recently arisen in New South Wales, and it may appear subsequently in Western Australia.

If this proves to be the case it will complicate the breeding work which has been undertaken locally, for some of our crossbreds possess Eureka parentage. Such a possibility serves to emphasise the great importance of making continuous determinations of the races of rust present locally.

Types of Resistance to Rust.

From the wheat breeding standpoint, resistance to stem rust of wheat may be placed in two main categories:—

(1) Physiological or seedling resistance.

(2) Mature-plant resistance.

With the knowledge that the stem rust fungus was not a single entity, but comprised numerous races which could only be separated by their modes of infection when grown on a differential set of seedlings, the breeding of rust resistant varieties appeared to have been greatly complicated.

It seemed that if no variety could be found that showed resistance to all races of the fungus, much crossing and re-crossing would be necessary to combine in one variety high resistance derived from numerous others.

Simplification of the problem arose, however, when it was shown that some varieties possessed seedling resistance to a group of races and that this seedling type of resistance was simply inherited. This meant that from the plant

breeder's point of view groups instead of single races were the units, and therefore the larger the groups the fewer would the necessary crosses be.

Seedling resistance of this kind is called physiological because it is due to some inherent quality in the constitutional or physiological make-up of varieties possessing it. Actually resistant varieties may be infected, but the fungus cannot establish itself to an extent that it can cause serious injury (see also page 6). It is generally accepted that a variety of wheat possessing seedling resistance to a race or groups of races, maintains its resistance throughout its life, under normal environmental conditions. Several wheats, notably those from the Kenya Colony in South Africa, possess this seedling type of resistance and since their discovery they have been largely used in crosses both in Australia and America. Some of these wheats have proved resistant in the seedling stage to as many as twenty races. The variety Eureka, bred in New South Wales, derives resistance of the seedling type from a Kenya parent, and until the recent advent of a new race it was highly resistant to all Australian races.

Another type of stem rust resistance is that known as mature-plant resistance. From about the fifth leaf stage onward, varieties possessing this quality develop a resistance which tends to be effective against all known races, although they may be susceptible to a number of these races in the seedling stage. Hope and H.44-24 are outstanding varieties of this kind, and in crosses with them it has been shown that the inheritance of mature-plant resistance is relatively simple and quite independent of the seedling type of resistance.

Thus the variety Warigo, which derives mature-plant resistance from Hope, is susceptible to race 34 in the seedling stage, but by crossing it with a variety possessing seedling resistance to this race both types of resistance could be combined. By combining different types of resistance the plant breeder ensures as much as possible that his varieties will remain resistant to new races which may arise.

BREEDING FOR RUST RESISTANCE.

During the rust epidemic of 1915 at Chapman Research Station, it was noted that a (Gluyas Early x Bunyip) crossbred showed some resistance, and it was subsequently released as the variety Nabawa. Since the appearance in Western Australia in 1925 of the rust race 34 the resistance shown by Nabawa and Gluyas Early does not appear to be of a very high order.

The following table of yields from the June planted wheat variety trial at Chapman Research Station in 1934 shows that under epidemic conditions the popular commercial varieties possess little true resistance to rust.

CHAPMAN RESEARCH STATION.

June Planted Variety Trial, 1934.

Variety.	Yield. bus.	lbs.	Maturity.
Noongaar	3	12	Very early.
Merredin	5	20	Early.
Gluyas Early	4	56	,,
Totadgin	3	46	,,
Geeralying	4	10	,,
S.H.J.	5	14	,,
Carrabin	6	54	,,
Comeback	4	40	,,
Nabawa (control)	3	29	Midseason.
Bencubbin	1	18	,,
Sutton	2	59	Late.

In view of the susceptibility shown by practically all wheat varieties in the 1934 epidemic, it was decided to commence breeding in Western Australia specifically for rust resistance. Since rust in severe form occurs so infrequently in Western Australia it is necessary, in order to select for resistance, to culture the rust and induce artificial epidemics. Consequently a rust garden was constructed in 1934-35 at the Merredin Research Station with brush walls 7-8 feet high and sprinkler irrigation. The major difficulties in the rust garden have been to over-summer the rust and to induce sufficiently severe epidemics. Plantings are now made at fortnightly intervals during the late spring and summer to carry the disease through the hot dry months. Heavy autumn infection appears to be a pre-requisite to abundant spring infection. On the whole, a fairly satisfactory technique has been developed to select for rust resistance under artificial conditions. During 1943 an additional rust garden was constructed at the Wongan Hills Research Station to accommodate the increasing volume of material being handled. The Western Australian Department of Agriculture is one of the few organisations endeavouring to breed for rust resistance under artificial conditions.

Plantings have also been made of crossbred material at Messrs. Drage Bros., Northampton, by the District Agricultural Adviser, Mr. Davenport. Until 1943, when valuable observations were made, little rust appeared in these plots, despite their being located in a rust-liable district.

American plant breeders observed fifty years ago that some of the more primitive wheats exhibited a high degree of resistance or total immunity to rust. Attempts at crosses between these and the common bread wheats failed to yield satisfactory commercial varieties, since, in general, there was a linkage between the undesirable primitive characters and rust resistance. However, in 1923, E. S. McFadden of the South Dakota Agricultural Experiment Station produced Hope, described as "an epoch making triumph in the wheat breeding world, because it was the first successful attempt to transfer by crossbreeding the highly disease resistant qualities of the Emmer species to a common bread wheat." Hope is the basis of several Australian rust resistant varieties, the most successful of which is Warigo, developed at the Waite Institute by Dr. I. F. Phipps and S. R. Hockley from a (Nabawa x Hope) cross made in 1931. Warigo was released to farmers in 1941-42.

Another variety used to some extent by Australian plant breeders was Webster, which was an importation into America from Russia made in 1913. It was from a cross between this variety and Federation that Dr. W. L. Waterhouse of the Sydney University produced Fedweb, which was first distributed to farmers in Western Australia in 1939 by the Department of Agriculture. However, this variety is too late maturing for W.A. conditions.

At the Glen Innes Experiment Farm in Northern New South Wales, severe rust epidemics occur almost annually. At this station Dr. S. L. MacIndoe successfully developed the Eureka varieties, from Kenya Crossbred C.6040. Although at first highly resistant they have since proved susceptible to the new rust race which has appeared in New South Wales. In Western Australia the Eureka varieties are very rust resistant, since the new rust race has not as yet appeared in this State. The Eureka varieties are of quite satisfactory straw and flour strength and have been used by Mr. Bateman of the Wongan Hills Research Station in crosses with Sutton and Gluclub, and at Merredin in crosses with Bencubbin and Bungulla.

The first cross specifically for rust resistance in Western Australia was made at Merredin between Webster and Bencubbin in 1934. Some 98 per cent. of the f.2 was discarded either for red grain colour or excessive beard. Of the remaining selections, several showed appreciable resistance to rust but were too weak strawed to have any commercial value. A careful survey was then made of the records of the Merredin Research Station, which showed that several of the Kenya varieties had been immune whenever rust appeared there. In general they were more resistant than the American varieties, Hope, Webster and Marquillo, earlier maturing and much stronger strawed. In 1937 Kenya C.6041 was crossed with Sword at the Merredin Research Station by Mr. E. C. B. Langfield. The Kenya crossbred C.6041, unlike the Kenya C.6040 parent of Eureka, is resistant both to the new race which attacks that variety in New South Wales and to all other known Australian races of rust. Selections for resistance were made from the white grained resistant segregates of this cross and continued as single plants and lines. The fourth generation lines were bulked for field trials and one of these under the farm number M.60 has yielded very well. Selection is proceeding to produce a "fixed" type, for possible release as a variety.

Reference has been made earlier to the different "types" of resistance available to the plant breeder, and of the possibility this offers of combining them to produce a variety which will remain resistant in the event of one resistant parent being attacked by a new race. The variety Warigo possesses "mature plant" resistance, whilst the "Kenya type" resistance is effective at all growth stages. The two types of resistance are inherited independently and the genetics for combining them in one variety has been successfully investigated by the Acting Cereal Specialist in New South Wales, Dr. S. L. MacIndoe.

Current breeding work in Western Australia includes the combination in one variety of the Kenya C.6041 type resistance with the Hope type possessed by Warigo. This ensures as much as possible that in the event of a new race arising which can attack either parent the variety will remain resistant.

Although not rust resistant in the sense that the Kenya and Hope varieties are, Kondut, a recent Western Australian production, is less affected by rust than are Bencubbin and Nabawa.

CARRY-OVER OF WHEAT STEM RUST.

In Australia the fungus causing stem rust of wheat persists from season to season in a very different way from that which occurs in cold countries in the Northern Hemisphere, where the red spores cannot survive the cold winter weather.

There the black resting spores formed as the crop matures in autumn, lie dormant through the winter, and in spring they germinate and cause infection of barberry bushes. From infected barberries the fungus spreads once more to the new season's wheat crop, when its carry-over is completed.

A totally different situation exists here, for in the first place the period between crops during which the fungus has to survive is a summer one, and in the second place, the black resting spores cannot fulfil their function in the general absence of the barberry. There is ample evidence that in Australia the fungus survives the summer period in the red uredospore stage, but so far as Western Australia is concerned the manner in which this is achieved is not yet fully accounted for.

In addition to attacking wheat, *Puccinia graminis tritici* also attacks barley, rye, and many grasses. It should be noted, however, that oats are not attacked, the stem rust found on that cereal being caused by a very closely related fungus, *Puccinia graminis avenae.*

In New South Wales, Dr. Waterhouse has shown that *P. g. tritici* bridges the summer period between wheat crops on self-sown cereals and grasses. For several years he has been able to collect living red uredospores from these hold-over hosts during each month of the year, thus fully accounting for the seasonal persistence of the parasite. Of the grasses, barley grass (*Hordeum murinum*), and a perennial grass, *Agropyron scabrum*, are the most important, but self-sown wheat is even more important.

It seems certain that a similar state of affairs will ultimately be demonstrated in Western Australia, but as yet opportunity for the monthly collection of rust, especially during the over-summering period between crops, has been limited.

The survival of rust on susceptible out-of-season cereals would appear to be more likely in the Eastern States, which have summer rainfall, than in Western Australia, where summer rains are unusual, although a carry-over on self-sown plants near soaks and other moist places cannot be altogether discounted.

However, a discovery of the utmost importance in connection with this problem was recently made. In December, 1943, a rust was recorded for the first time in W.A. on the perennial grass, *Agropyron scabrum*, which Dr. Waterhouse has since shown to be *Puccinia graminis tritici*, race 34. The specimen was found on the property of Mr. Frank O'Meaghan, near Borden, and it was growing in moist land at the junction of the Peenibup Creek and Pallinup River.

According to the Government Botanist, Mr. C. A. Gardner:—

"*A. scabrum* in Western Australia is confined to a southern sub-littoral tract corresponding to that area which receives more than five inches of rain during the six dryest months of the year (November-April). It is also noteworthy that during the summer months this area is favoured with high relative humidity and low evaporation, while no other area in temperate Western Australia possesses such a high summer rainfall."

Within this area, *A. scabrum* has been recorded from a number of centres, including Bridgetown, Manjimup, Stirling Ranges, Mourcourup, Esperance, and King George's Sound.

It would thus appear that the summer climatic conditions of the area in which *A. scabrum* is known to occur are more favourable for the persistence of wheat stem rust than those of any other area in temperate Western Australia.

WEATHER CONDITIONS IN RELATION TO EPIDEMICS OF RUST.

Fortunately in Western Australia weather conditions are seldom ideal for the development of rust, at least for lengthy periods, and in consequence serious outbreaks have been infrequent. In the main wheat belt areas serious epidemics occurred in 1915, 1917, 1934, and 1943, while in the much smaller Borden-Gnowangerup district additional outbreaks occurred in 1930 and 1939.

Rust may appear in autumn or during mild winters, but it is in Spring or early summer that it is most to be feared.

The occurrence of rust epidemics in years when heavy rains have fallen between January and April, and especially during March, has often been noted. (See Table.)

January to April Rainfall (points) in Rust Epidemic Years at Four Centres.

Year.	January.	February.	March.	April.	Total.	Average for period Jan.-Apl.
Chapman.						
1915	74	465	18	46	603	for 35
1917	...	...	301	72	373	years
1934	42	1	454	461	958	
1943	95	103	134	93	425	205
Moora.						
1915	93	253	75	94	515	for 43
1917	60	16	373	77	526	years
1934	182	15	482	238	917	
1943	87	36	275	103	501	244
Kellerberrin.						
1915	136	172	37	55	400	for 45
1917	260	10	493	74	837	years
1934	68	75	294	342	779	
1943	150	223	260	144	777	257
Mullewa.						
1915	179	370	89	123	761	for 45
1917	10	8	299	23	340	years
1934	138	17	483	378	1,016	
1943	83	285	393	50	811	243

It will be seen from the table that at four well-separated wheat belt centres the total rainfall during the period, January to April, considerably exceeded the average during each of four rust epidemic years.

As far as can be ascertained from existing records, epidemics of wheat stem rust have only occurred in Western Australia in years such as these, and therefore the relationship between this unusual raintall and epidemics subsequently in Spring or early summer, would appear to be a significant one. In all probability this phenomenon is associated with an autumn build-up of rust on susceptible plants such as barley grass, and self-sown or early sown wheat, and the overwintering of the fungus on these infected plants.

However, it should be clearly understood that epidemics of rust have not occurred in all years characterised by such conditions, nor would it be wise to predict that epidemics will never occur in years marked by their absence.

Before the fungus can develop to epidemic proportions in the Spring and early summer ideal conditions must be provided; these comprise an abundance of red spores, wheat plants still in a susceptible stage, and favourable weather conditions.

As we have seen, the red spores of the fungus are always present, and during a favourable period the extent to which the disease develops will largely be determined by the number of spores available for spread. The greater the number of initially infected plants the greater will be the number of spores produced within the period. Thus, if favourable conditions are experienced for a relatively short period only, the number of infected plants at the source may well be a major factor in determining whether or not the disease reaches epidemic proportions.

An essential factor for the development and spread of rust is moisture, and this must be accompanied by moderately cool to warm temperatures.

Ideal conditions are provided during sultry weather, or during periods when frequent light showers and heavy dews occur, especially if these are accompanied by a long succession of cloudy or overcast days.

A long succession of cloudy mornings followed by humid but not hot days, is especially favourable for an epidemic of rust. With these weather conditions moisture is retained on the leaves long enough to allow the red uredospores to germinate and enter the host plant.

CONTROL.

The most satisfactory way of avoiding injury from rust and a number of other fungal diseases also, is to use resistant varieties.

For many years it has been standard practice in W.A. to avert losses from flag smut in this way, and all new wheats bred by the Department of Agriculture must show high resistance to this disease. The wide popularity which the local variety Nabawa subsequently gained was largely due to this quality.

Similarly, it is hoped that rust resistant varieties capable of yielding as well as susceptible ones in rust free years, and maintaining those yields under epidemic conditions, will shortly be available to farmers.

With susceptible varieties control measures are based on the crop escaping damage by being too near maturity to be attacked when the disease reaches epidemic proportions. This can be achieved by early planting, growing early maturing varieties and applying superphosphate, which hastens maturity.

Early Planting.

The results recorded at the Chapman Research Station in 1934 show that earlier planting enables varieties to escape major damage, though as comparison with trials in earlier rust free years shows, they may have little true resistance.

CHAPMAN RESEARCH STATION, 1934.

Planting Date.	Variety.	Average Yield, 1934.	Average Yield, 1928/33.
		bus. lbs.	bus. lbs.
Mid April	Nabawa	23 7	9 48
Mid May	„	5 30	10 28
Mid June	„	3 33	10 30
Mid May	Gluyas Early	10 40	14 37*
Mid June	„ „	5 46	12 38
Mid July	„ „	1 36	8 29

* Average 1926/33.

SUMMARY.

1. Reference is made to the latest rust epidemic in Western Australia and the serious but infrequent incidence of the disease in the past.

2. The rust problem of the first settlers and the production of rust-escaping varieties by the early Australian breeders are described.

3. A description is given of the symptoms of the disease and the life cycle of the rust fungus.

4. An account is given of the physiologic races of stem rust, their origin, and changes which may occur in their distribution.

5. Types of rust resistance, and the breeding of rust resisting varieties with special reference to this State are given.

6. The mode of carryover of rust from season to season in Australia is compared with that existing in the Northern Hemisphere.

7. An account is given of the relationship between weather conditions and rust epidemics in W.A.

8. The principles of rust control are indicated.

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The Blackberry or Bramble.

(*Rubus fruticosus L.*)

G. R. W. Meadly.

SUMMARY.

A survey conducted in 1939 showed that approximately 500 acres of land in Western Australia were occupied by blackberry and indicated that with the exception of a few higher rainfall pockets the weed was not spreading to any extent in the area north of a line extending from Bunbury to Albany.

Experiments carried out were designed to compare the effects and costs of different concentrations of various chemicals and also the results of certain cultural measures in association with pasture establishment.

A five per cent. solution of sodium chlorate proved the most effective chemical used, but following the application of 625 lbs. per acre in five sprayings over a period of three years, a few weak plants still remained. Except for limited areas the cost would be prohibitive.

Although a weak solution of sodium arsenite had little permanent effect, it caused a drying of the above-ground portions, thus facilitating the destruction of the canes by burning. When the blackberry growth is tall, destruction or removal of the canes is necessary before the affected area can be ploughed.

Pasture establishment and subsequent judicious grazing, besides being more effective and less costly than chemicals, increased the productivity of a heavily infested area from a negligible quantity to that of a good permanent pasture.

1. INTRODUCTION.

The blackberry or bramble is native to Europe but is now naturalised in many countries. It occurs freely in South-Eastern Australia, particularly in Tasmania, and is also abundant in parts of New Zealand.

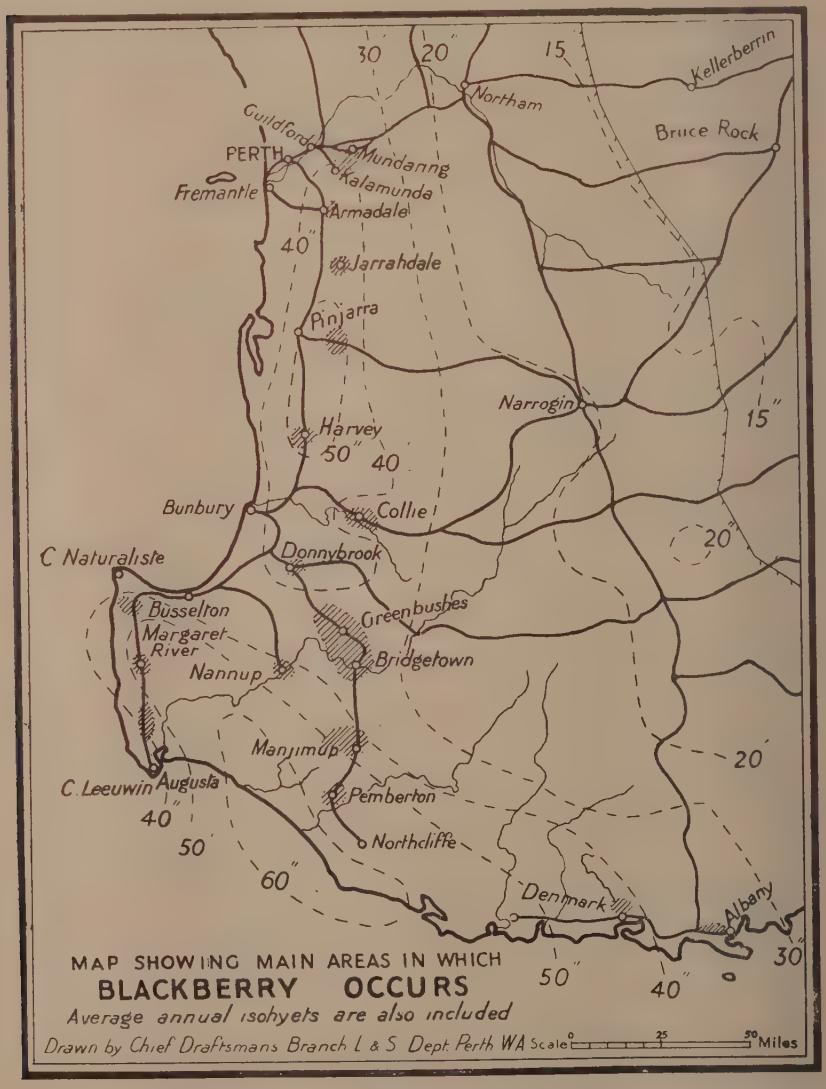
In 1939 an attempt was made to map the areas of infestation in this State and assess the significance of blackberry as a weed, at the same time securing information likely to be of use in devising a control programme. The survey conducted by officers of the Department of Agriculture revealed that the total area infested approximated 500 acres, of which three-quarters was located in the Balingup-Bridgetown district. Of this area 200 acres was considered suitable for agricultural purposes.

The main development occurs in valleys, although the pest has invaded hillsides, especially where the soil retains more than average moisture during the summer. In many cases heavy infestations can be linked with old mill sites and rural town sites. Frequently these were selected in gulleys which provided ideal conditions for the brambles often planted by the settlers.

Observations indicate that, with the exception of a few higher rainfall pockets such as at Jarrahdale and Dwellingup, blackberry is not spreading to any extent in the area north of a line extending from Bunbury to Albany. In places south of this line, however, especially in the heavier rainfall districts, rapid spread has been reported, particularly along water courses.

2. CHARACTERISTICS AND DISTRIBUTION.

The blackberry is a vigorous perennial which makes most of its growth during the spring and summer. The stems and leaves bear strong thorns and the plants often occur in dense thickets of 10 feet or more in height. Besides propagating by means of seeds, suckers and layers are also produced. Flowering commences in early summer.



As with a number of other weeds, much of the early spread and also some of the recent distribution has not been accidental. People wishing to have a ready source of blackberries for jam have planted canes but have failed to keep them

within bounds, with the result that further areas of infestation have been originated. Seeds and broken branches carried by running water are often deposited some distance from the parent plant, and there is ample evidence to show that birds are an important distributing agency.

3. INVESTIGATIONS.

As little basic information was available concerning the best means of destroying blackberries under the conditions prevailing in this State, early in 1940 a series of experiments was designed by the State Weeds Committee. The aims were to compare the effects and cost of different concentrations of various chemicals and weed-killing preparations, and also the results of certain cultural measures in association with pasture establishment.

(a) *The use of Weed Killers.*

(i) *Experimental procedure.* An area of heavily infested land on Mr. Blechynden's property at Bridgetown was selected as a site for this work. Because of the difficulty of isolating individual bushes of uniform size and the fact that the site selected carried an even growth of blackberry shoots, it was decided to spray plots 20 links x 20 links (1/250 acre) and to reduce to three the six replications proposed in the original plan.

The blackberry stand was dense and varied from two to four feet in height. The initial spray applications were made on 10th January, 1940, a hot, overcast and humid day.

Treatments were as follows:—

		%
1.	Sulphuric acid	2·5
2.	Acid sodium arsenite	
	Sulphuric acid	2·5
	Arsenic trioxide	0·6
3.	Sodium arsenite	
	Arsenic trioxide	0.6
4.	Sodium arsenite	5
5.	Arsenic pentoxide	1
6.	Arsenic pentoxide	5
7.	Sodium chlorate	1
8.	Sodium chlorate	5
9.	Atlacide	1
10.	Atlacide	5
11.	Defnakill	—
12.	Control	—

All solutions were applied in the form of a fine spray at the rate of 500 gallons per acre by means of a knapsack spray pump. No. 3 was prepared by mixing 1 lb. white arsenic ½ lb. caustic soda and 16 gallons of water and represents the solution used by Phillipps (2). Defnakill, a proprietary line containing arsenic, was mixed according to directions in the proportion of four gallons of solution to 50 gallons of water.

The following table lists this and subsequent treatments:—

Table 1.

Treatment.	10th January, 1940.	20th March, 1940.	20th November, 1940.	6th March, 1941.	20th January, 1942.	5th February, 1943.
1	500 gals. per acre	Burnt	250 gals. per acre	250 gals. per acre	...	...
2	,,	,,	,,	,,	...	...
3	,,	,,	,,	,,	250 gals. per acre	...
4	,,	,,	,,	,,	...	...
5	,,	,,	,,	,,	...	...
6	,,	,,	,,	,,	...	...
7	,,	,,	,,	,,	...	...
8	,,	,,	,,	,,	125 gals. per acre	125 gals. per acre
9	,,	,,	,,	,,	...	...
10	,,	,,	,,	,,	...	...
11	,,	,,	,,	,,	...	...
12	...	,,	...	...	...	...

(ii) *Results.* In order to estimate any differences in results due to treatments, plant counts were made on 4th November, 1940, 22nd August, 1941, and 29th October, 1942, 10 one-sq. link counts being made for each plot. The figures and analyses may be summarised as follows:—

Table 2.

Treatment.	Mean Number of Shoots per sq. link.			
	4–11–40.	22–8–41.	29–10–42.	12–10–43.
1. Sulphuric acid 2·5%	2·7	3·1	...	...
2. Acid sodium arsenite (H_2SO_4 2·5%, As_2O_3 1%)	1·7	1·7	...	...
3. Sodium arsenite (As_2O_3 0·6%) ...	2·3	2·6	3·1	...
4. Sodium arsenite 5%	3·8	2·9	...	...
5. Arsenic pentoxide 1%	3·4	3·0	...	...
6. Arsenic pentoxide 5%	2·6	2·2	...	...
7. Sodium chlorate 1%	3·1	1·8	...	...
8. Sodium chlorate 5%	2·0	0·2	0·6	0·2
9. Atlacide 1%	3·8	3·6	...	...
10. Atlacide 5%	2·8	1·4	...	...
11. Defnakill	2·2	2·9	...	...
12. Control	2·5	1·9	3·7	...
* Required difference for significance	1·4	1·6	0·7	...

Although all the chemicals used caused the foliage and portion of the canes to become dry, within a month of applying the sprays green shoots were apparent over the entire experimental area. The plant counts made in November, 1940, showed that the initial treatments and burning had no significant effect on the degree of regeneration of the weed, but at the same time observations indicated that some treatments, especially the 5% sodium chlorate, were affecting the vigour of the shoots.

*When the difference between any two means (averages) exceeds the required difference for significance this difference is considered to be due to experimental treatment and not to factors such as variations in the initial stand of blackberries and vigour of the plants.

Blackberry.

The following series of counts made on 22nd August, 1941, disclosed that the only treatment giving control (if we accept the 1% level of significance) was a 5% solution of sodium chlorate. The other treatments were without effect. As, at this stage, three applications totalling 1,000 gallons per acre of all the treatments had been applied during the 15 months, it was considered that little information of practical value would be secured by making further applications, with the

exception of 5% sodium chlorate. The sodium arsenite (0·6% As_2O_3) plots were continued temporarily for comparative purposes. The final count of the 5% sodium chlorate plots made on 12th October, 1943, showed that although control had been effected and the shoots were of a weak nature the blackberry had not been destroyed after the application (extending over three years) of 1,250 gallons of solution, representing 625 lbs. of sodium chlorate. At this date shoot counts were not possible on any other plots owing to the dense growth of brambles.

An interesting feature of this experiment was the effect of different chemicals on the botanical composition of the annual growth. In the spring of 1941, the controls carried mixed herbage of silver grass (*Vulpia* spp) subterranean clover (*Trifolium subterraneum*) and burr trefoil (*Medicago denticulata*); the 5% sodium chlorate and atlacide plots were silver grass dominant with legumes very few or absent, a condition apparent to a lesser degree with the weaker chlorate solutions; the 1% arsenic pentoxide plots were conspicuous owing to a dense growth of burr trefoil which was somewhat less abundant on the acid sodium arsenite plots; with the exception of blackberry shoots and moss there was no growth on either the 5% sodium arsenite or 5% arsenic pentoxide plots.

In the spring of the following year (1942), although grasses were still dominant on the chlorate plots, there was more volunteer growth of burr trefoil than in the previous year; apart from blackberry and moss the 5% sodium arsenite and 5% arsenic pentoxide plots were bare while on the remainder the supplementary growth was mainly burr trefoil, grasses being insignificant.

(b) *Multiple factor experiment involving pasture establishment.*

(a) *Experimental procedure.* This experiment was designed to incorporate the following factors:—

(i) The use of selected chemicals and mechanical means to promote burning.
(ii) Cultivation and pasture establishment.
(iii) Management of the pasture.

A site carrying a dense uniform stand of blackberry up to six feet in height was selected on the property of Mr. D. Walker, at Southampton, near Greenbushes, and the experiment laid out according to the plan.

Cut	B	A	A	B
5% sodium arsenite ...	B	A	A	B
5% sodium chlorate ...	A	B	A	B
Control	B	A	B	A
	Plough and Sow 1940		Fallow 1940 Sow 1941	

A—Perennial rye grass 4 lbs., cocksfoot 1 lb., midseason subterranean clover 4 lbs. per acre.

B—Phalaris tuberosa 3 lbs., midseason subterranean clover 4 lbs. per acre.

The slashing was carried out and the sprays applied at the rate of 250 gallons per acre on 11th January, 1940, a hot, humid, overcast day. Each treatment block measured 80 links x 50 links, representing 1/25 acre.

The area was burned on 19th March, the dry sprayed sections providing ample kindling material and ensuring the burning of the canes on the slashed and control sections. Owing to the late season, ploughing was delayed until 25th May and on 6th June, following cultivation and harrowing when many blackberry roots were removed, the 1940 sowings were made along with a dressing of 2 cwt. of superpho-phate per acre. On 22nd April, 1941, the fallowed section was cultivated, harrowed and sown as shown in the plan. As when making the previous sowing many root clusters lifted by the harrowing were removed from the plots. Following an initial application of 2 cwts. of superphosphate per acre, fertilizer has been applied in the autumn at the rate of 1 cwt. per acre.

On three occasions during three years coarse canes have been removed by slashing, entailing about two hours work for the entire period. The only other treatment has been systematic and heavy grazing with both sheep and cattle. At different times 12 cows and 35 ewes, along with 30 lambs, have been pastured for a day on the experimental area of 4/25 acre.

(b) *Results.* On 15th September, 1940, plant counts were made on the first series of sown plots. In the following summary the figures represent the means of 10 one-sq. link samples per plot:—

Table 3.

	A. (Perennial Rye grass)	B. (Phalaris)
Blackberry shoots ...	2·1	3·3
Sown species	2·8	2·5
(Grass + clover)	(2·1 + 0·7)	(2·1 + 0·4)

The detailed figures show that there were no significant differences due to either species or preliminary weed-killer or cutting treatments. Again the preliminary chemical treatments had no significant effect on the establishment of the sown species.

Plant counts made on the 1941 sown plots (fallow) are summarised in the following table:—

Table 4.

	A. (Perennial Rye grass)	B. (Phalaris)
Blackberry shoots ...	1·0	1·1
Sown species	5·9	7·0
(Grass + clover)	(3·9 + 2·1)	(4·2 + 2·9)

The 1941 sown series resulted in an excellent establishment of pasture species but Table 3 shows that, at least at this early stage, there was no difference between the effect of the different pasture mixtures on the number of blackberry shoots produced. An analysis of the complete figures for the plots and blocks shows that there was no difference between the blackberry shoots on the 1940 and 1941 sown areas, that is, no effect of fallowing. No differences due to the chemical or mechanical pretreatments were indicated either relative to the establishment of the sown species or the blackberry recovery.

Both sowings resulted in excellent pastures of all species, with the exception of cocksfoot, during the season following seeding. When last inspected in October, 1943, although some blackberry shoots were apparent, the weed was under control and a permanent pasture replaced the dense thicket of blackberries which confronted us when the experiment was commenced in 1940. Counts of blackberry shoots confirmed the impression that they were becoming less numerous, the means of 10 one-sq. link samples per plot being 0·4 and 0·5 for the perennial rye grass and Phalaris series respectively.

The original growth of blackberry on the experimental site, Mr. D. Walker's property, Southampton.

4. DISCUSSION.

The use of chemicals as an independent factor, if repeated at intervals, will serve to prevent seed formation and arrest the spread of blackberry, but destruction by this means under the conditions existing at Bridgetown would certainly prove a very lengthy and costly programme. Of the 11 chemicals applied, by far the most effective was a 5% solution of sodium chlorate, although following the application of 625 lbs. per acre during a period of three years a few weak plants still remained. Materials and labour had cost £25 per acre without completely destroying the plant. At a cost of £12 per acre, 1,250 gallons of sodium arsenite (0.6% As_2O_3) consisting of four applications over a period of two years prevented flowering and the vegetative spread of the weed but little more could be claimed for this treatment. It is to be expected that repeated defoliation over a number of years, provided the new shoots were not allowed to develop to any extent, would weaken the plants by sapping their reserves and eventually kill them. The experiments show, however, that treatment with a weak solution of sodium arsenite, unless supplemented by other measures, must be regarded as a method of control rather than eradication and under most conditions would entail frequent applications for many years—a costly procedure.

Pasture established on a heavily infested area, February, 1943, three years after the initial treatments. (The blackberry in the background had been checked by spraying.)

Experiments with chemicals conducted in the Eastern States have given comparable results. Prunster (3) working on an area of 160 acres of good flats at Dandenong, heavily infested with blackberry and Watsonia Meriana, concluded that, although some measure of eradication was evinced by repeated heavy sprays with arsenicals and chlorates, the results obtained did not justify the cost, especially since the land remained unproductive through soil sterilisation. Dandenong is 18 miles south-east of Melbourne, and the rainfall is 32 inches per annum. Further investigations conducted by the Council for Scientific and Industrial Research (1) at Bathow, New South Wales, showed that chlorates killed the aerial shoots but regrowth was both rapid and strong and the resulting shoots, if anything, were more resistant to subsequent spray.

Phillips (2) has secured good results on river flats along the Balingup Brook with sodium arsenite (0.6% As_2O_3) supplemented with atlacide following a varying number of applications. On sections of this property at least, however, the chemicals have not represented an independent factor as competition, particularly from perennial grasses such as Paspalum (*Paspalum dilatatum*) and kikuyu (*Pennisetum clandestinum*), along with grazing by stock have proved effective contributory factors. This conclusion is supported by Phillips' statement that "areas of our flats which three years ago were so thickly covered with brambles that it was impossible to walk through them are now densely coated with Paspalum, which attained an average height of about three feet last season in spite of the land having been subject to numerous arsenical sprayings during the preceding two or three years."

The results of the multiple factor experiment demonstrate conclusively that where land can be brought under the plough and perennial pasture species can be established, this is the best means of controlling blackberry. In most cases ploughing cannot be carried out until the canes have been destroyed or removed.

Subsequent results showed that there was no difference between the efficiency of the methods used in the experiment, but there was considerable variation in the cost of the treatments prior to burning.

TABLE 5.

	Per acre of dense growth.		
	Materials.	Labour.	Total.
	£ s. d.	£ s. d.	£ s. d.
Cutting	—	7 10 0	7 10 0
Spraying with 5% sodium arsenite	3 10 0	1 15 0	5 5 0
Spraying with 5% sodium chlorate	3 10 0	1 15 0	5 5 0
Control (no treatment) ..	—	—	—

On the experimental site the control plots adjoined sprayed sections which, being dry, burned fiercely and aided the burning of the controls. If an effective fire cannot be secured without some pretreatment to provide dry kindling material, the necessary drying should be induced by a weak chemical solution as the chemical used has no significant effect on the blackberry re-growth. Sodium arsenite containing 0·6% As_2O_3 is suitable for this purpose, the cost of material for one acre being 12s.

Similar results relative to the effect of perennial pastures on the growth of blackberry have been recorded by the Council for Scientific and Industrial Research (1). Mixtures based on perennial rye grass and white clover or subterranean clover were found suitable provided the pastures were grazed—preferably with sheep—and some attention devoted to dealing with the regrowth to prevent it from re-infesting the area.

Pasture establishment and subsequent grazing, besides being more effective and less costly than chemicals for the control of blackberry, increases the productivity of a heavily infested area from a negligible quantity to that of a good pasture. Experience has shown that permanent results are seldom obtained with perennial weeds unless, when suppressed their place is taken by desirable species, and this is clearly manifest with the blackberry.

5. CONCLUSIONS.

Where infested land can be ploughed and perennial pasture species established, the blackberry canes should first be removed by the cheapest means available. If a severe fire cannot be secured without first killing the leafage at least portion of the area should be sprayed with a weak solution of a chemical such as sodium arsenite at the rate of approximately 250 gallons per acre of dense blackberries in order to provide kindling material. A suitable solution of sodium arsenite may be prepared by thoroughly mixing one pound of white arsenic with one half pound of caustic soda and then adding an equal quantity of water. When the water is added, heat is generated and the solids dissolve rapidly. When completely dissolved, this concentrate should be made up to a volume of 16 gallons and stirred thoroughly each time a quantity is removed from the container.

Although the amount of arsenic contained in this solution is small and field experience indicates there is little risk, it is inadvisable to graze stock in paddocks that have just been sprayed.

A general view of the pasture on the experimental site, October, 1943. (The blackberry beyond the plots had been sprayed and burned during the previous summer.)

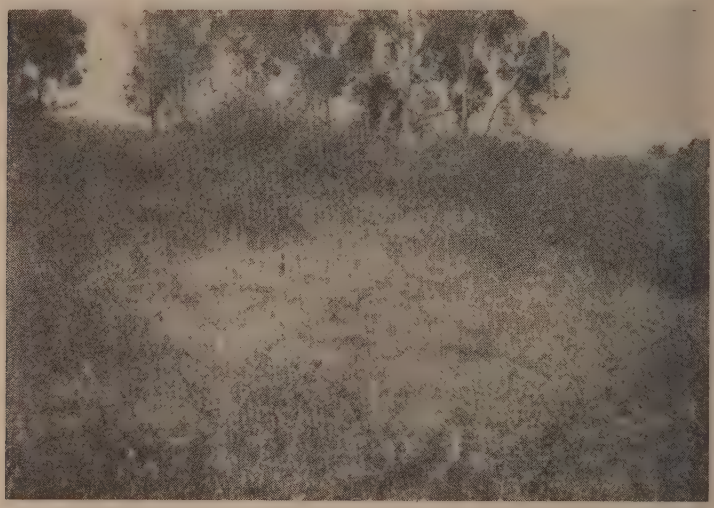
If the plants are sprayed in January they can be burned in March when any regrowth will be killed. If a good burn is not secured, some slashing may be necessary. The area should be ploughed as early as possible in the autumn, followed by cultivation and harrowing to produce a suitable seed bed. During these workings quantities of blackberry roots are brought to the surface and as many as possible should be removed.

A satisfactory pasture mixture consists of 4 lbs. of perennial rye and 4 lbs. of mid-season subterranean clover per acre, but different conditions may necessitate some modification. To ensure a permanent type of rye grass and the correct strain of subterranean clover, Government certified seed should be sown. The pasture should be allowed to become established without grazing during the first season, and when grazing is commenced it should be arranged to prevent the growth from becoming rank, thus exposing the blackberry shoots and at the same time securing the maximum returns from the pasture. Our experience indicates that heavy grazing with sheep for short periods is most damaging to the blackberry. At flush periods mowing may prove more effective and convenient. Any long canes that develop should be removed by cutting, but if a good ground cover of pasture is produced this entails little work.

Although the cost prevents sodium chlorate from being used over extensive areas, it may be applied when only a few plants require attention, especially when they are growing among rocks or along fences where ploughing is not possible. A five per cent. solution, i.e. one half pound per gallon of water, should be used.

As previously stated, a weak solution of sodium arsenite is suitable for killing the top growth preparatory to pasture establishment where a good fire cannot be secured without first providing kindling material. It is also useful for "spotting" suckers growing in pastures. As an independent method, it can be employed to prevent seed production and vegetative spread, particularly when the plants

are growing in places that are not readily accessible. Although a degree of control is effected, eradication in a reasonable time by this method alone, however, cannot be expected. Directions for preparing the solution are given on page 26.



One of the five per cent sodium chlorate plots, October, 1943 (Note the thermos.) The final spray treatments were applied to the surrounding plots in March, 1941.

6. ACKNOWLEDGMENTS.

Thanks are due to the members of the South-West Weeds Committee for their collaboration and assistance in selecting suitable sites, and to Messrs. D. Walker, Southampton and Blechynden, Bridgetown, for placing land at our disposal. Mr. Walker's hospitality and assistance with the experiments located on his property were also appreciated. The author is indebted to the State Weeds Committee, under the Chairmanship of the Under Secretary for Agriculture (Mr. G. K. Baron Hay), for sponsoring these experiments; to Mr. A. B. Cashmore, Research Officer, Council for Scientific and Industrial Research, for assistance in planning the details and interpreting the results and to Mr. A. M. Tindale, Dairy Instructor, Department of Agriculture, for help with the field work.

Thanks are also extended to the Chief Draftsman, Lands and Surveys Department, for arranging the preparation of the map and to Mr. C. A. Gardner, Government Botanist, for the drawing of blackberry.

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3. Prunster, R. W. (1940): "Notes on the control of Blackberry, Watsonia, Bracken and Ragwort in Victoria," *Journal C.S.I.R.*, Vol. 13, No. 3, Aug., 1940.

Maps of Perth and Suburbs.

A matter of interest to farmers and pastoralists, both at home and during visits to the City, has been brought to our notice by the Chief Draftsman of the Department of Lands and Surveys.

He has advised that a Metropolitan Road Map attractively printed in various colours, showing made and unmade roads, tram and bus routes, Road Board and Municipal boundaries, recreation grounds, parks, gardens and other useful information, is available at the Public Room of the Department of Lands and Surveys, Cathedral avenue, Perth. Price 5s. unmounted, or £1 1s. mounted on calico with battens as a wall map. With the mounted copies a bound index to every street, road, etc., in the Metropolitan Area is supplied free, but if required with an unmounted copy the cost is 1s. extra.

The scale of the map is two inches to a mile and the size 30in. x 40in.

A similar map to the above, in black and white, 5ft. x 7ft., on a scale of four inches to a mile, is available with index and mounted on calico with battens at a cost of £3 3s.

A 10-mile series or topographical maps showing station properties, water supplies, fencing, roads, tracks, etc. over the pastoral areas of the State is in course of preparation and will be available for issue towards the end of the year.

The Chief Draftsman of the Department is available to advise the public on any mapping matters.

More About Contour Banks.

N. Davenport, Agricultural Adviser.

The use of contour banks for the control of soil erosion due to water action, is now long past the experimental stage. The practice has proved so highly successful that it is now universal. A description of these contour banks and the method of construction has already been given in a previous issue of this Journal*, September, 1938.

The purpose of this article is to describe the construction of contour banks on an area of Mr. A. Rob's farm at Northampton and the resultant effect in controlling water erosion, and on the rehabilitation of the area.

This area is a paddock of approximately 70 acres, which in its virgin state carried jam and wattle timber. The soil, which is typical of the district, is a brown gritty sandy loam. It is quite liable to water erosion. It was cleared in 1916 and since being fallowed in 1917, has been cropped ten times and fallowed five times up to and including 1940, i.e., over a period of 23 years.

The majority of the surface has a slope of 6-7% rising to 14% over a small section in the South-West corner.

Erosion was first noticed in 1934 and became progressively worse, particularly after heavy rains in 1939. It was last cropped in 1937. The decision was then made that further cropping was unwise and that the paddock would be let out to grass for an indefinite period. By the end of 1940, even after three years

* "Soil erosion—the construction of contour banks," September, 1938.

under grass the erosion was still increasing. There were many small ruts and gutters over the whole area, in some places quite difficult to cross with machinery. There was also one gutter which was 2-3 feet deep over most of its length.

To arrest the erosion, early in 1941 Mr. Rob decided to have the paddock contour drained. An inspection was accordingly made to determine the best outlet for the water from the drains formed by the banks and hence the direction in which they should fall. The large gutter or small gully at the east end of the paddock was chosen as the most suitable outlet for most of the drains; the remainder were to feed into natural creek bed on the south boundary. It was decided also to construct two banks separate from the above system on the slope adjacent to the west boundary and where a gutter had formed.

Plate 1 gives an aerial view of the paddock, showing the main gully and natural creek bed into which the drains empty.

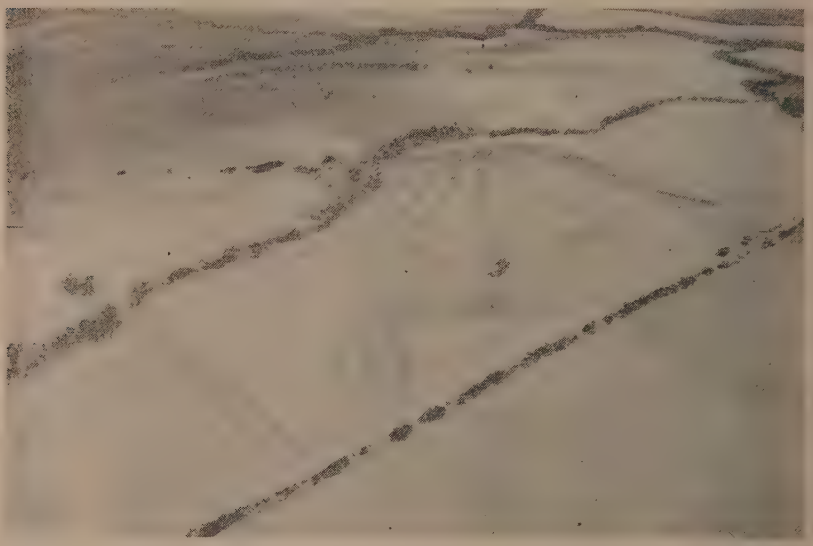


Plate 1. Aerial view of paddock showing contour banks, main gully and natural water course.

LAYING OUT BANK LINES.

As the majority of the slope had a grade varying between 6-7%, the vertical height between banks was determined from appropriate tables at six feet.

From experience gained by the construction of contour banks at the Chapman Research Station, the banks were given a fall of ½%, or 6in. in 100 feet except for the last five chains at the lower end where the fall was increased to ¾%, or 9in. in 100 feet. This increased fall was given to ensure a quick getaway of water should the banks be fully loaded through heavy rain.

A surveyor's dumpy level and measuring staff were used to lay out the lines. Several hundred small pegs were provided. It was considered suitable to have the pegs no closer than 20 feet to mark out the line, also that it was sufficient to step the distance between pegs as any error made in assessing this distance was not practically significant in altering the line of the bank and hence its fall.

The distance between pegs was checked periodically to ensure approximate correctness.

After pegging out the lines it was found necessary to move some pegs a small distance up or down the slope to form a continuous curve and so overcome the unevenness of the surface.

FORMING THE BANKS.

The banks were ploughed with a five furrow mouldboard plough with lever adjustment for the front and rear. A heavy disc plough is more suitable for the work, but one was not available. On the first trip the off furrow slice was thrown on to the pegs from the top side and on the return trip the same was done from the bottom side. Two ordinary rounds were then ploughed, making a ploughed strip of six plough widths. The fourth round was made on the ploughed area, throwing the off furrow slice on to the peg line as before. A fifth round was ploughed outside the fourth. Two more rounds were again made, similar to the previous two except that instead of throwing on to the peg line for the sixth trip, the furrow slice was thrown about 12in. to 18in. away from it and the seventh followed as in normal ploughing.

The result was a broad based bank with a broad shallow drain on its top side.

Plate 2 shows one of the first four contour banks constructed, photographed early the following year after it had well settled. The centre of the bank is 10 inches above the lowest point of the drain.

Plate 2. Showing bank after settling, crown 10 inches above lowest point in drain.

This would collect the run off water from the area above it and because of the gradual fall of the bank that which did not soak in would quietly flow away and eventually find its way into the side gully and so to the natural creek bed.

However, the recognised height of the top of the bank from the bottom of the drain is 15 inches, and this was not obtained. It is necessary to plough 6in. deep to produce the required bank in seven rounds, and as the plough could not be set deeper than 4in., insufficient soil was moved. It was decided, therefore, to plough further rounds until the correct height was obtained, accordingly a further five rounds were done. The first ploughed into the centre and the second followed on as ordinary ploughing. The remainder were made where necessary and the final result was an evenly formed bank and drain.

The same procedure was adopted for the next three drains. Unfortunately time and a shortage of manpower did not permit of making this number of trips for the remainder of the banks. The usual seven rounds were ploughed in each case and it was arranged to build them up further with a road grader. However, the grader could not later be obtained and these banks remained as they were ploughed with about 11 to 12 inches between the top of the loose bank and the upper drain.

Where the banks crossed gutters and depressions they were built up to the proper level by shovelling soil from the lower side. This had to be done at a considerable number of places. Plate 3 shows where a bank crossed a rather large gutter. The height of the bank was maintained by shovelling earth from the bottom side. Where the banks were formed on the steeper slopes of 11-14%, more ploughing had to be done on the top side to form a suitable drain.

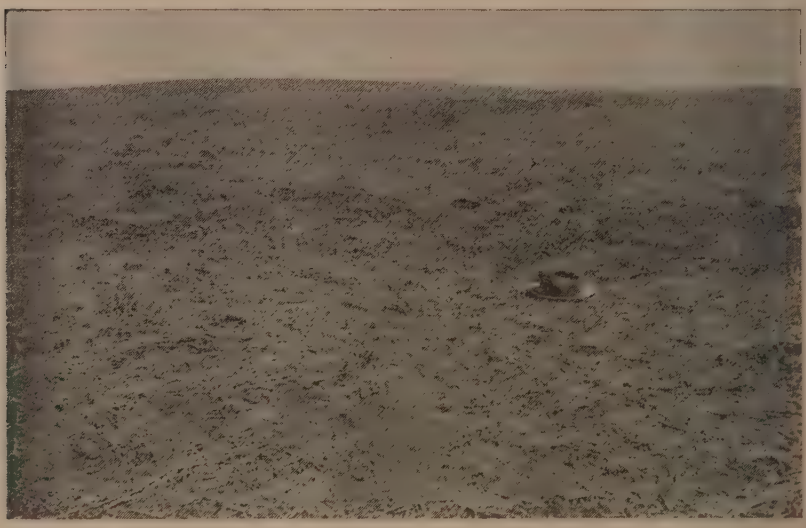


Plate 3. Showing where bank has crossed a gutter and has been built up with shovelled earth.

EFFECT OF THE BANKS.

The banks were formed during the first week of July, 1941. During the next month heavy rains fell. In no place were the banks broken through. All run-off water was caught by them and flowed quietly along the drains and out into the gully or creek. There was no erosion in the drains. The following year Mr. Rob

decided to crop the paddock. It had been under grass for four consecutive years and required breaking up. It was ploughed "round and round" with a disc cultivating plough with seed box attached and planted at the same time. Any ruts in the banks were filled in by means of a shovel.

By harvest time, after having had two winter rains on them, the banks had settled considerably and machinery could be taken over them in any direction. No trouble whatever was experienced when driving the harvester over the banks.

The banks have received no further treatment, although it is proposed to renovate them by ploughing out the drains on to the banks during the coming winter.

A recent inspection of the paddock showed that the effect of the contour banks had been to control water erosion completely. Principally by the cultivation, many of the small gutters had been filled up with soil, and the larger ones to a lesser extent. Plate 4 shows one large gutter which has been largely filled up and Plate 5 illustrates the improvement effected in the main gully. Natural grasses had become established in it and this had the effect of retarding the rate of flow of water and hence deposition of soil particles carried by it.

Plate 4. Fairly large gutter which has appreciably filled up.

COMMENT.

During operations it became obvious that ploughing to a depth of 5in. at least is required and preferably 6in. to do the work in seven rounds satisfactorily. When ploughing the last five rounds of the first four banks the soil was so loose that the plough sank deep into it and the mouldboards pushed the soil aside instead of lifting and placing it in position. A disc plough is decidedly preferable for the work.

The making of contour banks is quite a simple procedure once it has been demonstrated. They can be formed with ordinary farm equipment and therefore their construction is within the capability of any farmer.

There are many thousands of acres which through water erosion have lost much of the fertile top soil and on which the gutters and gullies are so far

Plate 5. Showing improvement in the main gully.

developed that they cannot any longer be worked economically with machinery. Again, there are those many areas of country which are still arable and the only signs of erosion are small gutters over which machinery can readily pass. Quite a proportion of the fertile top soil has been washed away, however, and from this stage the deterioration will be comparatively rapid.

In both cases sound contour draining will arrest the erosion and eventually with suitable farm management restore the fertility to its proper level.

Its soil is one of the principal assets of a nation and it behoves those who would reap its gifts to reciprocate by maintaining its fertility.

Warning!

FIRE RISK WITH NITRATE OF SODA BAGS.

Owing to the large quantities of oxygen which can be supplied by nitrate of soda in the presence of fire, jute bags which have contained this fertiliser can constitute a real fire risk, particularly when stored in inflammable buildings such as are frequently found on farms.

Not that nitrate of soda alone is dangerous or inflammable, but when inflammable material such as bags is coated with it, a spark from a car or tractor, or a lighted cigarette, can very easily start a fire. Once started, these fires are extinguished only with considerable difficulty owing to the excess oxygen present, which permits of burning deep into a stack from which ordinary atmospheric oxygen is excluded. Wetting of the bags, without washing thoroughly, and subsequent drying, will increase the risk as by this means particles of nitrate of soda are distributed throughout the fibres of the bag.

Users of this fertiliser are advised, therefore, that the only satisfactory method of removing this fire risk is to wash the bags *thoroughly* in several changes of water, after having turned them and shaken off as much fertiliser as possible.

Home gardeners purchasing small lots in paper bags should ensure that containers are promptly destroyed after use of the fertiliser.

Studies in Cereal Hay Production in Western Australia.

1.—THE INFLUENCE OF TIME OF CUTTING UPON YIELD.

E. J. Underwood and A. J. Millington.

Conservation of fodder is an integral part of farming practice over a large part of the world's agricultural regions. In the southern agricultural areas of Australia, with their predominately Mediterranean type of climate, conservation of materials capable of being fed to stock in the long dry summer period, when pasture and crop growth is at a standstill, is acknowledged to be essential. The "growing period" of the year has to be exploited to provide for the non-growing period. The principal conserved feeding stuffs under Australian conditions, are cereal hays and grains, "meadow" or pasture hay, lucerne hay and cereal and clover silage. It is difficult to obtain even approximately accurate figures for the amounts of grain conserved for feeding to stock on farms but cereal hay, i.e., wheaten and oaten, is easily the most important conserved feeding-stuff. According to the Australian Year Book (1940) the total area harvested for hay, for the years 1930-9 inclusive, was almost 3 million acres per year, with an average yield of 23.4 cwt. per acre. 98% of this area was devoted to cereal hay of which 58% consisted of oaten hay and 42% wheaten hay.

In the light of these figures, and of fodder conservation schemes in which every inducement is given to the farmer to conserve more hay, no emphasis need be given to the necessity for obtaining as much information as possible of the factors which govern the yield and nutritive value of this important crop. Numerous experiments have been carried out on farms and experiment stations throughout Australia for many years on the influence of variety and of a range of cultural and manurial practices on the yield of cereal hay but, with the exception of the pioneer work of Perkins and co-workers (1912, 1914) with wheaten hay in South Australia, no work has been done on the effect of different times of cutting, i.e., of stage of maturity or on conditions of curing.

The experiments with wheaten and oaten hay described below were designed to go some way towards filling this gap in our knowledge. They cover two seasons' work, one with wheat and one with oats. It was originally intended to carry out two seasons' work on each cereal and to extend the work to cover a study of the effect of varying curing conditions. But the exigencies of the war situation have made it necessary to curtail this programme. It was considered better to publish the results at this admittedly incomplete stage rather than to postpone publication for an indefinite period.

Location of Experiments.

The experiments were conducted at the Avondale Research Station, Beverley, situated about 60 miles south-east of Perth. The climate is of the "extreme" Mediterranean type. That is, the winter and spring period (May to October) is mild and wet and all crop growth normally takes place during this period. The summer and early autumn period (November-April) is hot and dry. The soils at Beverley on which both experiments were conducted were grey-brown sandy loams. Such soils are fairly typical of those on which much of the cereal hay is grown in W.A. for commercial purposes.

Experimental Layout and Procedure.

In each instance the experimental design was superimposed on a uniform crop grown on fallow and planted with normal farm machinery. All plantings were

made in late May with 1 cwt. superphosphate per acre annd satisfactory growth followed.

In a layout capable of statistical analysis, which is highly desirable in order to reduce the effects of soil variation and other factors to a minimum, the order in which the plots are cut is determined by chance. If the binder is used each plot must therefore adjoin a pathway. This necessitates more than 50% of the experimental area being cut out as passageways for the binder.

1941.—In 1941 insufficient suitable wheaten crop was available at Avondale for this purpose. Recourse was therefore made to a systematic design in which the plots were cut successively from both sides of six pathways. This gave twelve plots each two chains long and one binder cut wide, as the basis for assessing the yield of hay on each cutting date. Nine successive weekly cuts were made from the stage when about half the ears were emerged on 10/9/41 to the almost mature stage on 4/11/41 and a final cut at the fully ripe stage on 20/11/41.

The weight of green material from each plot was obtained at each cutting and a large composite sample taken for moisture determination. In this way the total weight of dry material at each cutting could be calculated. The weight of hay from each plot was taken after curing in the paddock in stooks slightly smaller than normal in size. The samples for moisture determination, chemical analysis and digestibility studies were taken during the chaff-cutting process carried out at the completion of curing. From the differences in weight of dry material as cut and after curing the curing losses were calculated.

The variety "Baroota Wonder" wheat, a tall-growing hay type notable for its ability to remain green to the base of the stem, was used.

1942.—Sufficient of the oat variety "Wongan" was available in 1942 for a randomised block layout with five replications. Plots six chains long and twelve feet wide were arranged in pairs so that any plot could be cut when desired. Six successive cuts at 10-day intervals were made from the ear emerging stage on 10/9/42 to the doughy to mature stage on 29/10/42. The plot yields of cured material and the samples were obtained as in the previous year. The stooks were of normal size.

Yields of Hay.

In Table I the yields of cured hay at each cutting are presented for the wheat and the oats. The yields are expressed as cwts. per acre of oven-dry material. The yields are also shown in graphical form in Figures I. and II. The actual yields of ordinary air-dry hay are, of course, somewhat higher than those presented for cured hay, since the moisture content was of the order of 7-10 per cent.

With the wheat there is a steady increase in yield from the "ear emerging" to the "late milk" stage about 21 days after "full bloom." There is a slight fall in yield seven days later i.e., at the "early dough" stage, followed by further reductions in yield as the plants approach full maturity. The apparent rise in yield at the fully mature stage is due to the fact that the yield at this stage refers to the weight of dry material as cut, i.e., without any curing losses. If this figure be compared with the earlier yield of dry hay as cut, given in Table II it is seen that there is actually a small reduction in yield at complete maturity compared with the "almost mature" stage.

With the oats there is a similar steady increase in yield after the first cut, at the time of panicling. This continues until the "early dough" stage is reached about 28 days after full bloom and is followed by a very slight fall in yield at

the subsequent cutting 10 days later. The drop in yield at the most mature stage is not so marked as in the case of the wheat. In fact the difference in yield at the "early dough" and the "doughy-to-mature" stages is not statistically significant.

These results compare very well with those of Perkins et al (1912, 1914) obtained with wheaten hay from six cuts between full bloom and maturity but with no plot replications. These workers found the maximum yield of cured hay to occur at the "full-dough" stage, 29 days after full bloom, in one year's experiment and at the "late milk" stage, 20 days after full bloom in the second year's experiment.

In a trial carried out in California with wheat and oats cut at four stages of maturity, namely "blossom," "milk," "soft dough" and "ripe," Hendry (1925) found the highest yield of cured hay in each case to occur at the "soft dough" stage, with the yield at the "milk" stage very little lower.

Table I.

YIELDS OF CURED HAY.

(Cwts. per acre oven-dry material.)

Wheat, 1941.			Oats, 1942.		
Cutting Date.	Growth Stage.	Yield.	Cutting Date.	Growth Stage.	Yield.
		Cwts. per acre.			Cwts. per acre.
10–9–41	Half ears emerged ...	31·5	10–9–42	Panicling	20·4
16–9–41	All ears emerged ...	36·0	...	...	...
23–9–41	Full bloom	38·6	18–9–42	Full bloom	27·3
30–9–41	Flowering complete ...	40·8	...	...	...
7–10–41	Grain half-formed ...	41·9	28–9–42	Grain forming ...	28·8
14–10–41	Late milk	48·6	7–10–42	Milky	32·0
21–10–41	Early dough	46·5	16–10–42	Early dough; stems yellowing	36·6
28–10–41	Late dough	41·1	...	...	...
4–11–41	Almost mature ...	38·7	29–10–42	Doughy to mature ...	34·1
20–11–41	Fully mature	43·3*	Difference for significance (P = ·05)		2·9

*This figure refers to the weight of dry material as cut. It is therefore not comparable with the other figures, which refer to *cured* hay. No curing was necessary with this cut.

Losses in Curing.

A number of workers particularly Watson (1939), have drawn attention to the large losses of total dry material and especially of the more digestible portions of the crop, in ordinary haymaking. He gives the average losses in making meadow hay, without special appliances, as 22% for dry matter, 44% for starch equivalent, and 34.6% for digestible crude protein.

The complete absence of any similar figures for losses in the curing of cereal hay, at least under Australian conditions, emboldened the authors to publish the data set out in Table II, although it should be emphasised that the experiment was not specifically designed to obtain information on this important matter. An experiment designed to obtain more critical data on the magnitude and nature of curing losses, under different conditions of curing, is already under way.

The figures for yields of oven-dry hay as cut, i.e., before curing, were obtained by simple calculation from the total weights of green material on the day of cutting and the dry matter content of this material determined from samples taken at the time of weighing. The yields of oven-dry cured hay were obtained in the same way from the total weight of cured hay and the dry matter content of samples of this hay taken at the time of weighing.

Table 2.

LOSSES IN CURING OF WHEATEN HAY.

(Cwts per acre oven-dry material.)

Cutting Date.	10th Sept., 1941.	16th Sept., 1941.	23rd Sept., 1941.	30th Sept., 1941.	7th Oct., 1941.	14th Oct., 1941.	21st Oct., 1941.	28th Oct., 1941.	4th Nov., 1941.	20th Nov., 1941.
Yields as cut (dry weight)	39·5	41·5	48·2	54·4	49·3	60·4	57·0	52·5	44·5	43·3
Yields after curing (dry weight)	31·5	36·0	38·6	40·8	41·9	48·6	46·5	41·1	38·7	.
Losses in Curing (dry weight)	8·0	5·5	9·6	13·6	7·4	11·8	10·5	11·4	5·8	. .
Percentage curing losses	20	13	20	25	15	20	18	22	13	.

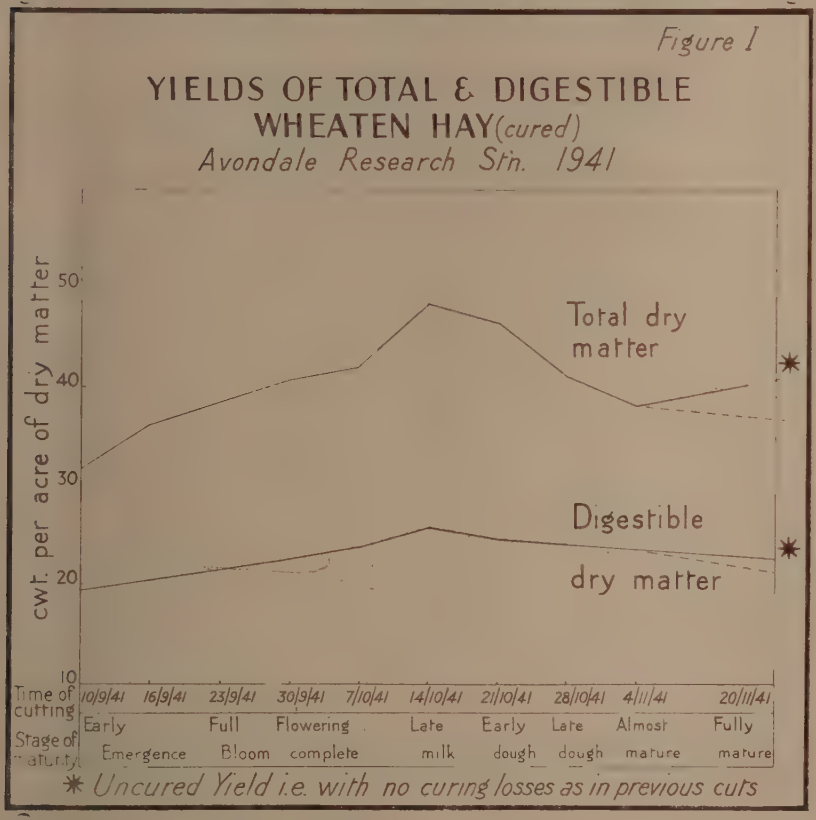
The actual loss of dry matter during the curing process ranged from 5.5 to 13.6 cwt. per acre with a mean loss over the whole range of 9.3 cwts. per acre. The percentage loss ranged from 13 to 25 per cent. with a mean of 18 per cent. However with seven of the nine cuts the loss ranged only from 13 to 20 per cent. which, considering the differences in the nature of the material being cured and in the times and periods of curing inevitable in the experiment, is a very narrow range. The exceptionally high loss obtained in the fourth cut taken on 30/9/41 is probably influenced largely by an error in the dry matter determination on the original green material since the calculated yield of hay "as cut" on this date is appreciably higher than would be expected from the yields obtained immediately before and after.

It should be made clear that these figures do not allow of sound deductions to be made in relation to the influence of stage of maturity on curing losses, since the conditions of curing for each cut were quite different. The conditions, however, were not dissimilar, except in the first cut, from those occurring in good farm practice. As previously pointed out, the stooks were slightly below normal in size.

DISCUSSION.

It is apparent that the total yields of hay from a wheaten or oaten crop is considerably influenced by the stage of maturity which it has reached at the time of cutting. Under the conditions of these experiments the maximum yields can be expected from wheat cut about three weeks after full bloom, i.e., at the "late milk" stage, and from oats cut about four weeks after full bloom, i.e., at the "early dough" stage. Later cutting, i.e. at a more mature stage, does not result

in an increased total yield of hay. In fact, there is a small but definite decrease in total yield of hay both with wheat and oats, as the crop more completely approaches maturity.

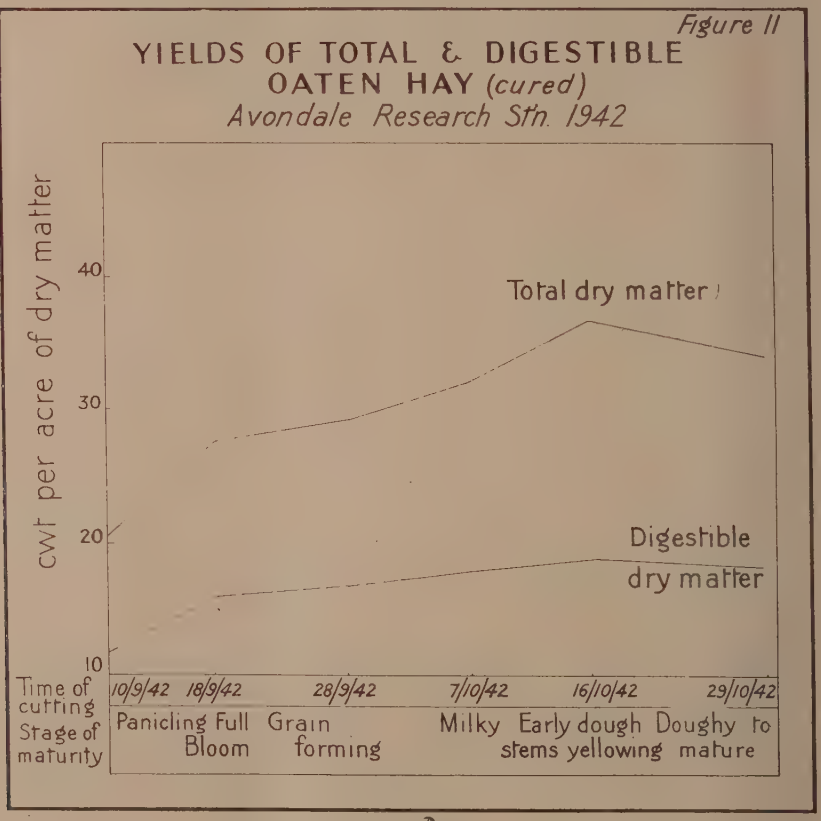


Two points of practical significance arise from a consideration of this question of the correct time to cut cereal hay for maximum yield. One is that it is the stage of maturity rather than the length of time after full bloom which is important. In areas, such as the eastern wheat belt of W.A. where the hot summer weather comes in more quickly, the stage of maximum yield would be expected to be reached in shorter time after "full bloom" than the three or four weeks found in these experiments. The second point concerns the length of time taken to cut hay. In ordinary farm practice this extends over a period ranging from several days to several weeks. Obviously if the farmer is to obtain the greatest yields of hay he will have to start cutting at such a time as will enable the greatest proportion of his crop being cut at the stage of maximum yield.

It is not proposed to discuss at this point the losses which occur during curing. From the results obtained in these experiments with wheat it is clear that these are in the order of 15-20 per cent. of the total dry material in the crop as cut. These losses if they occur generally, are of sufficiently high order to

warrant a very thorough study of their nature and of their cause so that the cutting and curing conditions conducive to minimum losses can be worked out. Such studies are, as already pointed out, already under way.

The question of the relation of time of cutting to chemical composition and digestibility will be discussed in the following paper.



SUMMARY.

Experiments carried out at the Avondale Research Station, Beverley, on the effect of different times of cutting upon the yields of wheaten and oaten hay are described.

Ten successive weekly cuts with "Baroota Wonder" wheat were made from the stage of ear emergence to full maturity.

Six cuts at successive ten day intervals were made with "Wongan" oats from the time of panicling until the grain was at the "doughy to mature" stage.

The stage of maturity at which both the wheat and oats were cut was found to have a marked effect upon yield.

With the wheat the maximum yield was obtained when the crop was cut three weeks after flowering, at the "late milk" stage.

With the oats maximum yield was obtained when cut four weeks after flowering, at the "early dough" stage.

In both cases later cutting i.e., nearer full maturity, resulted in lower total yields.

The losses of total dry matter during curing in the field were determined for the wheaten hay. For seven of the nine cuts which were cured this loss amounted to 13-20 per cent.

The need for caution in applying these results directly to other varieties and other districts is stressed.

ACKNOWLEDGMENT.

Grateful acknowledgment is made to the Manager of the Avondale Research Station (Mr. W. A. Human) and his staff for their assistance with the field work connected with these experiments.

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Studies in Cereal Hay Production in W.A.

II. THE INFLUENCE OF TIME OF CUTTING UPON THE CHEMICAL COMPOSITION AND DIGESTIBILITY OF WHEATEN AND OATEN HAY.

E. J. Underwood and R. J. Moir.*

In any attempts to evaluate the factors governing cereal hay production it is obvious that it is not only the total yields which have to be considered but the chemical composition and the digestibility, since nutritive value is determined by composition and digestibility. Countless experiments, both in this country and abroad, have shown that the yield and nutritive value of all crops are influenced largely by the stage of maturity at which the crop is cut or grazed. With the exception of the pioneer work of Perkins and co-workers (1912-1914) with wheaten hay in South Australia, no work has been carried out on the influence of stage of maturity on yield and nutritive value of cereal hay under Australian conditions. The effect of this factor on the yields of wheaten and oaten hay in one district in W.A. has been described in the previous paper (Underwood and Millington, 1944). The present paper deals with the same experiments, the details of which, in regard to design and location have been already given, but is mainly concerned with the question of composition and digestibility. In addition, some attention is devoted to the average composition of wheaten and oaten hay as ordinarily cut in W.A.

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Average Chemical Composition of Wheaten and Oaten Hay.

Before considering the experimental results it was felt that the average composition of wheaten and oaten hay as ordinarily cut on the farm in W.A. would be of interest. Samples of hay or chaff from farms throughout the wheat-sheep areas of W.A. and from the Metropolitan Grain and Chaff Market (Perth) have been collected over a number of years for various purposes. These have been analysed and the mean results, the standard error and the range of values obtained for each constituent are presented in Table I. They represent a wide range of varietal, cultural and curing conditions and, presumably also, of stage of maturity at cutting time, and in addition they include samples intended for home consumption on the farm and for sale through ordinary commercial channels.

Table 1.

AVERAGE COMPOSITION OF CEREAL CHAFF.

(Percentage on dry matter.)

	Crude Protein.	Ether Extract.	Crude Fibre.	N-free Extract.	Total Ash.	Calcium. (Ca).	Phosphorus. (P).
Wheaten—	%	%	%	%	%	%	%
Mean (20 samples) ...	5·6	2·0	28·0	58·8	5·7	0·14	·16
Range	4·6–6·9	1·1–3·3	22·0–32·7	53·8–66·4	3·7–7·5	·09–·26	·13–·24
Standard Error ...	0·17	0·14	0·71	0·85	0·30	0·01	0·01
Oaten—							
Mean (13 samples) ...	5·5	3·3	28·3	57·4	5·5	0·17	0·18
Range	3·8–7·8	2·4–4·8	22·0–35·5	50·8–64·7	3·3–7·9	·12–·26	·11–·29
Standard Error ...	0·34	0·24	1·1	1·3	0·43	...	...

The figures in Table I reveal a number of important points concerning the general composition of cereal hay and chaff. It is clear that there is no significant difference in average composition between wheaten and oaten chaff and that considerable variation exists in the various constituents in each case. Apparently such factors as time of cutting and curing conditions are more important in determining the composition of the hay than the cereal itself, i.e. whether wheat or oats. The variation in the ether extract is of little practical significance, in view of the smallness of the actual amounts involved and the varying proportion of the extract which is true fat. Differences due to analytical methods are also of importance in the case of this constituent. Our own and other investigations have shown that very long extraction and fineness of grinding is necessary with some samples in order to obtain maximum figures.

The wide range of values for crude fibre and crude protein are of great importance from the point of view of feeding value and the factors determining this variability need working out. For instance, there is some evidence that a higher protein level is accompanied by higher digestibility. However, it is obvious that even the cereal hays of highest protein content must be looked upon as poor sources of protein compared with most feeding-stuffs. They are also, at the best, only poor to moderate sources of calcium and phosphorus.

There is a remarkable absence of published data on the composition of Australian cereal hay or chaff. Brunnich (1926) gives an average figure for Queens-

land wheaten hay which is almost identical with the W.A. mean figure in respect to crude protein and ether extract but appreciably higher in fibre content and much higher in total ash. In South Australia Perkins *et al* (1912, 1914) obtained the very high mean value of 8.3 per cent crude protein on the dry matter for seven cuts of wheaten hay in 1912, compared with 5.2 per cent for a similar series of cuts in the same variety obtained in 1914. This latter figure is very close to the mean value given above for the protein content of W.A. wheaten hay. The "standard" American figure (Morrison, 1937) for wheaten hay indicates that in America this feeding stuff is on the average a rather better source of protein and ash than in W.A.

The writers have been unable to find any published figures for Australian oaten hay with which to compare our own. Many American publications, however, notably those of Hendry and Woll (1925), Thatcher (1934), Sotola (1937) and Morrison (1937), give much higher figures for protein content than those submitted for W.A. oaten hay in Table I.

Effect of Time of Cutting on Chemical Composition.

The composition of the cured wheaten and oaten hay at each time of cutting and the stage of growth at these times is presented in Tables II. and III.

Table 2.

EFFECT OF ADVANCING MATURITY ON COMPOSITION OF WHEATEN HAY (CURED).

(Percentages on dry matter.)

Cutting Date.	Stage of Maturity.	Crude Protein.	Ether Extract.	Crude Fibre.	N-free Extract.	Total Ash.	Calcium (Ca).	Phosphorus (P).
		%	%	%	%	%	%	%
15–9–41	Half-ears emerged ...	7·0	1·6	29·4	56·7	5·3	·27	·13
16–9–41	All ears emerged ...	7·1	2·0	31·2	54·4	5·3	·35	·14
23–9–41	Full bloom	5·6	1·7	26·9	60·5	5·3	·31	·12
30–9–41	Flowering complete ...	4·3	2·5	25·8	62·2	5·2	·29	·11
7–10–41	Grain half-formed ...	4·6	1·7	25·0	63·8	4·9	·30	·13
14–10–41	Late milk	4·5	2·0	28·4	59·9	5·2	·25	·15
21–10–41	Early dough	4·5	1·4	27·1	62·5	4·5	·25	·12
28–10–41	Late dough	4·2	1·5	27·8	6_·0	4·5	·21	·10
4–11–41	Almost mature ...	4·2	1·5	29·8	60·0	4·5	·20	·14
20–11–41	Ripe	3·7	2·7	25·6	64·1	3·9	·33	·14

The only consistent and definite effect of stage of maturity on composition, as revealed by these figures, is on the protein content. In both the wheaten and oaten hay there is a steady fall in protein content from the early cuts at and before flowering until the time when the grain is practically mature.

TABLE 3.

EFFECT OF ADVANCING MATURITY ON COMPOSITION OF OATEN HAY (CURED).

(Percentages on dry matter.)

Cutting Date.	Stage of Maturity.	Crude Protein.	Ether Extract.	Crude Fibre.	N-free Extract.	Total Ash.	Calcium (Ca).	Phosphorus (P).
		%	%	%	%	%	%	%
10–9–42	Panicling	7·9	1·6	31·2	52·1	7·2	·19	·15
18–9–42	Full bloom	7·3	1·7	31·5	53·1	6·4	·19	·14
28–9–42	Grain forming ...	7·3	1·8	31·4	52·6	6·9	·11	·14
7–10–42	Milky	5·3	2·0	31·9	55·8	5·0	·14	·14
16–10–42	Early dough plants yellowing	4·3	2·2	30·7	57·8	5·0	·11	·14
26–10–42	Doughy to mature ...	4·8	2·8	29·2	58·0	5·2	·11	·12

The values for crude fibre, ether extract, total ash, phosphorus and N-free extract show no correlation with stage of maturity and in fact vary comparatively little from the first to the last cuts. The calcium content tends to fall with increasing maturity in both the wheat and the oats but the effect is not marked.

A similar lack of correlation between chemical composition (other than protein content) and the stage of maturity of wheaten hay was found by Perkins *et al* (1912, 1914) in South Australia, by Sotola (1937) with wheat, oats, barley and rye hay in Washington State and by Hendry and Woll (1925) with the same four cereal hays in California.

The Nature and Value of Digestibility Trials.

During the last hundred and more years the means whereby the nutritive value of feedings stuffs can be measured and compared have slowly but surely improved. The first step was to compare the gross weight of different feeds necessary to produce a particular live-weight increase in animals. The next step was to base this comparison not only on the gross weight of foods but upon their chemical composition, since it soon became clear that animals require not simply so many pounds of food but such an amount as would supply them with certain quantities of protein, fat and carbohydrates. This method for the evaluation of foods based on their total content of organic constituents, as found by chemical analysis, was then improved to include only the so-called "digestible" constituents, as found by actual digestibility trials on animals. This method although now known to be open to considerable error in interpretation, represented a great advance and is still the basis of most feeding tables and the best feeding practice.

It should be emphasised that the digestibility of a particular feed is not a constant thing. It varies with different species and individuals, with the level of feeding and with the nature of the rest of the ration. Properly interpreted, however, digestibility determinations enable a more useful and more accurate

assessment of the nutritive value of a feed to be made than any other means within the scope of most investigators. It is this fact that makes digestibility trials such valued, and frequently exploited, tools in the hands of nutrition workers.

The determination of the digestibility of a food and its components consists essentially in measuring the total amount of the food and its various components consumed by an animal over a given period and the amount of these same constituents excreted in the faeces over the same period. The difference between the two is regarded as the amount digested by the animal and the proportion digested is the "digestibility coefficient." In actual fact the material excreted in the faeces does not consist only of undigested food, so that the digestibilities determined in this way are not "true" but "apparent" digestibilities. The "true" digestibility is invariably higher than the "apparent." "True" digestibilities are, however, rarely determined and, except for special types of work, are not so useful as the "apparent" because the amount of material excreted in the faeces which is *not* undigested food, is governed to a large extent by the amount and nature of the food itself. In actual practice, therefore, apparent digestibilities are the more valuable guide to the value of a food as a source of energy and protein.

Bearing these facts in mind it was considered that the additional information on the nutritive value of cereal hay at the various growth stages to be obtained from digestibility trials would more than repay their trouble and expense. It was decided to use sheep for this work because of the increasing importance attached to cereal hay as a drought feed and summer supplementary feed for this animal. The results with sheep are not, of course, necessarily applicable to horses but with increasing mechanisation the horse will become less important, relative to other stock, as a consumer of cereal hay.

It should be emphasised further that the digestibility results strictly apply only to sheep fed entirely or very largely on the cereal hay in question. When fed with appreciable amounts of other feeds "the associative effect of feeds" becomes important in modifying the digestibility and nutritive value of the hay itself. In the case of protein this effect may assume considerable significance, as will become apparent later.

The Digestibility of Wheaten Hay.

Digestibility trials were carried out with six of the ten cuts. These were the first, fourth, fifth, sixth, seventh and tenth cuts. Five merino wethers, about two years of age, were used for each cut. They were each fed 600 or 700 gm. (or about 1½ lb.) of the chaff in two portions daily, according to appetite, and in addition each sheep received daily a small supplement consisting of 6 gm. bone-meal, 3 gm. dried yeast, 3 gm. salt and 0.5 ml. codliver oil. In all the cuts except the first there were food residues with some of the sheep. The composition of these residues did not differ significantly from that of the ration except in the tenth cut where there was some selection of the mature grain. The residues with this sample showed a consistently higher fibre and lower protein content than the chaff. The digestibility coefficients are therefore slightly higher in this cut than would have been the case if no selection had taken place.

Each trial ran for 14 days, the last nine of which constituted the collection period. The sheep were weighed at the beginning and end of each trial. During the trials with the first, fourth, fifth and tenth cuts the mean live-weights of the experimental animals showed little change; with the sixth and seventh cuts there was a mean live weight loss of 3.0 and 6.6 lbs. respectively.

The mean digestibility coefficients are presented in Table IV. The range of values obtained with individual sheep was sufficiently close to warrant the use

of average values in this way. In the trial with the fifth cut, however, the values obtained with one of the sheep were abnormally high. These were therefore excluded and the values used in their places determined by the missing data formula proposed by Allen & Wishart (1930) and modified by Yates (1933).

TABLE 4.
DIGESTIBILITY COEFFICIENTS OF WHEATEN HAY.

Cutting Date.	Stage of Maturity.	Dry Matter.	Organic Matter.	Crude Protein.	Crude Fibre.	N-free Extract.	Ether Extract.
		%	%	%	%	%	%
10–9–41	Half ears emerged ...	59·9	62·0	48·7	57·0	67·0	46·0
30–9–41	Flowering complete ...	55·7	58·9	37·4	46·7	66·7	63·9
7–10–41	Grain half formed ...	56·7	59·3	29·6	49·7	66·3	62·4
14–10–41	Late milk	52·6	54·9	29·0	41·3	63·4	24·5
21–10–41	Early dough	52·6	55·4	16·5	37·2	64·7	59·6
20–11–41	Ripe	52·6	55·2	0·2	33·1	64·9	75·0

In all constituents, except ether extract, which has a very variable "apparent" digestibility, the first cut has the highest digestibility coefficients. In the case of dry matter, organic matter and N-free extractives the later cuts have lower digestibilities than the earlier but the differences are quite small and bear no constant relationship to the stage of maturity. With crude protein and crude fibre, on the other hand, the later cuts have markedly lower digestibility coefficients. The values for protein are exceptionally low. It is significant that at complete maturity the digestibility of the hay is not significantly lower than at the "early dough" stage, cut four weeks earlier

These results are quite similar to those obtained by Perkins *et al* (1914) with wheaten hay using horses, except in the case of crude protein. These workers obtained much higher digestibility coefficients for this constituent. The lowest level was 53.9 per cent at the "late milk" stage. They also found the protein digestibility to be slightly higher at maturity than in the first cut at the "full bloom" sage.

In digestibility studies carried out with sheep on Albit wheat, which is a very much later maturing variety than most Australian wheats, Sotola (1937) found the digestibility of the total dry matter, the crude fibre, N-free extractives and crude fat to increase slightly from the milk to ripe stages but there was a small decrease in digestibility of the protein. The protein digestibility even at the ripe stage, however was considerably higher (54.9%) than in our samples.

The Digestibility of Oaten Hay.

For the determination of the digestibility of the six cuts of oaten hay six merino wethers were used and the trial laid out in the form of a Latin square. In this way each sheep in each trial was receiving a different cut determined by chance and six separate results were obtained for each of the six cuts. Statistical analysis of the results was rendered easier by this means.

Each sheep was fed 700 gm. of chaff daily, plus the small mineral and vitamin supplement as in the previous trial. The rations were well consumed in all cases. There were no residues. As before each trial ran for 14 days, the last nine of

which represented the collection period. The live weights of the sheep were well maintained during each trial.

The mean digestibility coefficients are presented in Table V. The range of values with individual sheep was quite small.

Table 5.
DIGESTIBILITY CO-EFFICIENTS OF OATEN HAY.

Cutting Date.	Stage of Maturity.	Dry Matter.	Organic Matter.	Crude Protein.	Crude Fibre.	N-free Extract.	Ether Extract.
		%	%	%	%	%	%
10–9–42	Panicling	57·1	5 ·6	49·9	60·6	57·6	35·2
18–9–42	Flowering	58·0	58·6	53·5	59·8	58·9	47·3
28–9–42	Grain forming	57·2	57·9	58·6	58·5	57·6	58·2
7–10–42	Milky	54·3	55·0	44·	51·4	57·5	60·8
16–10–42	Early dough; plants yellowing	50·9	51·2	29·3	46·6	55·9	61·5
29–10–42	Doughy to mature grain	53·5	54·3	42·6	45·5	5 ·9	70·0
.E. ...	... ...	1·01	0·83	2·6	.·58	0·74	...

The only constituent in which there is a steady fall in digestibility with advancing maturity is the crude fibre. The digestibility of the crude protein is also appreciably lower in the more mature cuts than in those cut earlier. In the case of the dry matter, organic matter and N-free extractives the later cuts have also in most cases, lower digestibilities than the earlier, but the differences are small and bear no constant relationship to the stage of maturity. In fact with the exception of fibre, there is an actual general rise in digestibility from the "early dough" to the "doughy to mature" stage cut thirteen days later.

In these respects the overall picture is similar to that of the wheaten hay. The chief differences lie in the actual magnitude of the digestibility coefficients. The figures for dry matter and organic matter do not differ greatly in the two cereals but the digestibility of the protein and the crude fibre does not fall to the same low level in the oats as in the wheat. The N-free extractives on the other hand are appreciably more digestible in the wheat than in the oats at each growth stage.

In the experiments of Sotola (1937) with Markton oats, an extremely late maturing variety, little difference was found in digestibility between the milk and the dough stages but in all constituents a definite rise in digestibility was obtained in passing from the dough to the ripe stage. Our figures are not strictly comparable since we did not have a sample of oats at the fully ripe stage but the general position is very similar. As in the case of wheaten hay Sotola obtained a much higher protein digestibility in his oat samples than we obtained in the present investigation. It should be pointed out, however, that this worker and Perkins and his colleagues were investigating hays of appreciably higher protein content. The "apparent" digestibility of protein such as we and the above workers have determined, is bound to be influenced by the actual total protein content of the hay, because the total faecal nitrogen is all considered as undigested protein. A portion of this faecal nitrogren is actually of metabolic origin and the amount

bears a more or less constant relationship to the amount of food consumed and the chemical composition of the food, other than protein content. Obviously, therefore, the lower the protein content of the hay the higher the *proportion* of faecal nitrogen of metabolic origin and the lower the "apparent" digestibility of the protein.

Yields of Digestible Nutrients.

By combining the total yields of dry hay, presented in the previous paper, with the composition and digestibility results it is possible to work out the effect of stage of maturity on the yields of total digestible material and of the different digestible nutrients. Some of these such as digestible ether extract and ash are of little significance and others such as crude fibre and N-free extractives are important but impossible to interpret because of the very arbitrary nature of the determinations themselves. Consequently the yields, in cwts./acre, of digestible dry matter, of digestible protein and of total digestible nutrients (T.D.N.) only will be considered. These are presented for both the wheat and oats in Table VI. The yields of digestible dry matter are also shown graphically in Figures I and II in the previous paper (Underwood and Millington, 1944). The total digestible nutrients (T.D.N.) figure is estimated by adding the sum of the digestible crude protein, crude fibre and N-free extractives to the digestible ether extract multiplied by 2.25. It gives a rough but very convenient measure of the available energy value of a feed.

Table 6.

YIELDS OF DIGESTIBLE NUTRIENTS.

(Cwts. per acre dry matter.)

Cutting Date.	Growth Stage.	Digestible Dry Matter.	Digestible Protein.	* Total Digestible Nutrients.
	Wheat.			
10–9–41	Half-ears emerged	19·5	1·1	19·5
30–9–41	Flowering complete	22·7	0·7	23·7
7–10–41	Grain half-formed	23·8	0·6	24·4
14–10–41	Late milk	25·6	0·6	25·6
21–10–41	Early dough	24·5	0·3	25·1
20–11–41	Ripe	22·6†	0·3	23·8
	Oats.			
10–9–42	Panicling	11·6	0·64	10·8
18–9–42	Full bloom	15·8	0·89	14·9
28–9–42	Grain forming	16·5	0·93	15·7
7–10–42	Milky	17·4	0·69	16·9
16–10–42	Early dough ; plants yellowing ...	18·6	0·49	18·4
29–10–42	Doughy to mature	18·2	0·55	18·1

* Total Digestible Nutrients = Digestible (Protein + Fibre + N.F.E. + (Ether Extract × 2·25)).

† Based on yield of dry matter as cut, *i.e.*, without any curing losses.

The digestible dry matter and T.D.N. figures, as would be expected from the low percentages of ether extract, are sufficiently close in each case to warrant consideration together.

The yields of total digestible nutrients per acre follow the same trends as the yields of total dry hay (see previous paper). In both the wheat and oats the maximum yield of digestible material occurs at the same growth stage as the maximum yields of total dry hay. For the wheat this is at the "late milk" stage three weeks after full bloom and for the oats at the "early dough" stage, four weeks after full bloom. The drop in yield of digestible dry matter or total digestible nutrients obtained by cutting earlier or later than this is exceedingly small, however, with the exception of the first cut in each case. This cut was obtained at a much earlier growth stage than would ever be attempted in ordinary farm practice.

The yields of digestible crude protein follow a very different trend. Here there is a definite disadvantage in late cutting, particularly in the case of the wheat. This is due to the fact that both the protein content and the "apparent" digestibility of the protein fall with advancing maturity. The effect is not nearly so marked with the oats but it is equally evident that cutting oaten hay before the time of expected maximum yield of total or digestible dry hay is essential if maximum yield of digestible protein is to be obtained.

Discussion.

The results as a whole, including those of the previous paper, call for some comment at this stage. It is evident that W.A. grown wheaten and oaten hay, unless cut so early that there is a very considerable sacrifice of total yield, must be regarded as rather poor quality feeding stuffs. At all stages of maturity, which might be looked upon as normal for ordinary farm practice, the dry matter is only 50-57 per cent. digestible and the protein is still less digestible. When this low protein digestibility is linked with the low total protein content of cereal hay it is seen that such hay is an exceedingly poor protein feed. Thus at the stage of maximum yield of total and digestible dry matter, as revealed by these experiments, both the wheaten and oaten hay contained only 1.3 per cent. of digestible protein. This is not sufficient to supply even the maintenance requirement of an adult sheep consuming the hay to the limit of appetite. It exemplifies the very poor quality of cereal hay in this respect and the necessity for feeding with the hay some feed or feeds richer in protein. Alternatively the cereal hay should be used as a supplement to grazing which has a protein content *higher* than the hay itself, not lower as is frequently the case in the late summer in W.A.

The finding that the effect of stage of maturity on the yield of digestible dry hay closely parallels its effect on yield of total dry hay is of considerable interest. Obviously the improved digestibility and composition (apart from the protein) of the earlier cuts is not sufficient to compensate for the lower total yields. In the later cuts, i.e., after the "late milk" and "early dough" stages, there is, except for the protein, little change in digestibility or composition but there is a small drop in total yield of hay which results in a reduced yield of digestible dry matter. There is therefore, an overall loss by cutting later than at the recommended times and only in the case of total digestible protein is there a significant gain in yield from cutting earlier than at these times. The proportion of total and digestible protein in wheaten and oaten hay is not large enough at any reasonable, practicable time of cutting, however, to warrant consideration of this factor to the detriment of others such as total yield. The hay cutting pro-

gramme on the farm should therefore be arranged so that as high a proportion of the hay crop as possible is cut at the "late milk" to "early dough" stage since this results in the highest yields of both total and digestible dry matter.

It is realised that there are a number of factors other than yield, composition and digestibility which require consideration in this question of the correct time to cut hay. Palatability, mechanical loss and selection by stock are obvious examples. No really critical data were obtained on these matters in these investigations but the oaten hay (fed chaffed) was apparently equally well liked at all six growth stages. The wheaten hay, on the other hand, was most palatable in the first cut, made at a comparatively immature stage. The tenth cut made at complete maturity was, judging by the number and amount of the food refusals, as well liked as the fourth, fifth and sixth cuts, but some slight selection of grain and refusal of the straw was made by four of the five sheep, although it was well chaffed. Cuts of hay made at as late a stage of maturity as this, or near to it, when the grain is fully formed or practically fully formed, is inadvisable because of the waste in feeding due to rejection of straw. A considerable proportion of the nutritive value of the hay at this late stage resides in the grain instead of being spread throughout the whole plant. It is also inadvisable because of the ease with which the grain, at this mature stage, is lost during handling.

A further argument against late cutting of hay is the loss of carotene (Vitamin A precursor) which results, although the conditions of curing are also exceedingly important—in determining carotene content. Any factor, and cutting at the correct time is one, which helps to maintain a good, i.e. green, colour in hay also helps to maintain a good carotene content. This is important where the hay is to be fed with grain or as a supplement to dry grazing, both of which are very low in carotene. The whole question of the relation of cutting and curing conditions to the carotene content of cereal hay is already under investigation and will form the subject of a later publication.

Another matter, which is of more than academic interest, should be mentioned. In all the above work the conventional analyses, including crude fibre, and N-free extractives obtained by difference, have been used. Many workers have pointed out the unsatisfactory nature of these determinations, particularly with roughages, where these two analytical groups together make up the greater proportion of the total material. Both the crude fibre and the N-free extractives may vary considerably in chemical makeup between different samples of the same class of feeding stuff and between feed and faeces in the same digestibility trial. A number of suggestions for improvement through separate estimations of cellulose, lignin and so on have been made. Such determinations are neither easy to carry out nor to interpret but they would represent a considerable advance on the present unsatisfactory position. An attempt to evaluate the data of the above experiments by more detailed studies of these carbohydrate fractions is being made by one of us (R.J.M.) and will form the subject of a separate publication.

SUMMARY.

The range of values and average composition of a series of samples of W.A.-grown wheaten and oaten chaff are presented.

The composition was found to be very variable but there was no significant difference between "average" wheaten and "average" oaten chaff.

The experiments described in the previous paper were extended to include the effect of the different times of cutting of wheaten and oaten hay on com-

position and digestibility. The digestibility trials were carried out with mature merino sheep.

The stage of maturity at which the wheat and oats were cut for hay had a marked effect upon protein content but no consistent effect upon any other constituent.

In both the wheaten and oaten hays the protein content was found to fall consistently with advancing maturity.

The protein and the fibre were markedly more digestible and the total dry matter slightly more digestible in the earlier cut hays. In the case of the wheat the "apparent" digestibility of the protein fell to exceedingly low levels in the more mature hay.

The yields of digestible dry matter closely paralleled the yields of total dry hay.

The maximum yields of total digestible nutrients were obtained by cutting the wheaten hay at the "late milk" stage and the oaten hay at the "early dough" stage. These were also the times of maximum total yield of hay.

The significance of these results is discussed; the importance of factors other than yield, composition and digestibility is pointed out; and the fact that ordinary wheaten and oaten hay must be regarded as a roughage very low in available protein is stressed.

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Clothes Moths and Carpet Beetles.

C. F. H. Jenkins, Government Entomologist.

Clothes moths and carpet beetles are amongst the most destructive of household pests, but on account of their retiring habits their presence is often overlooked until an infestation has become well established, and extensive damage has been done. Both types of insect, however, may be kept in check by periodic attention and the same control measures are effective against both beetles and moths.

CLOTHES MOTHS.

There are two common species of clothes moth in this State, and although the damage done by both is almost identical the habits of the two species are somewhat different.

General Description.

The webbing clothes moth, *Tinvola biselliella* Humm., is probably the commoner species, and is uniform buff or straw coloured. The case-bearing clothes moth, *Tinea pellionella* L., is slightly darker than the preceding species, and bears three rather indistinct spots on the forewings. Both species are small insignificant moths measuring up to ½ inch across the expanded wings.

The webbing clothes moth, enlarged and natural size.
(After Gibson and Twinn)

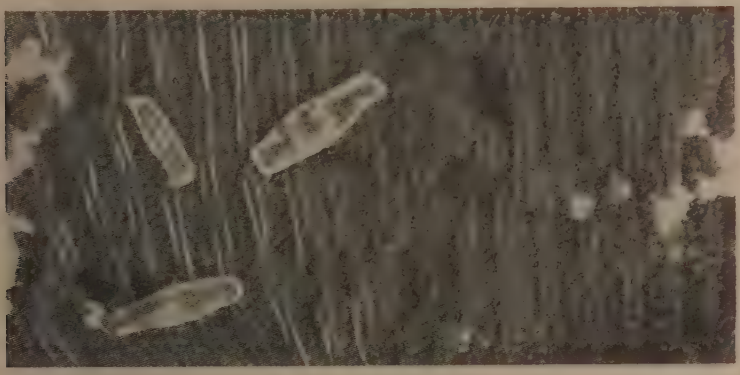
Habits and Life History.

Moths may be seen flying both by day and night, but they shun the light, and are most often met with in ill-lighted and little disturbed situations. The moths, of course, are not responsible for the damage done to fabrics, but are the parents of the small white caterpillars which do the actual injury.

The moths lay a hundred or more tiny white eggs on almost any kind of fabric or material of animal origin, such as wool, feathers, fur, felt, etc. The eggs hatch in about a week or more, according to the time of year, and the tiny caterpillars commence feeding. They are creamy white in colour with dark heads and measure about half an inch in length when fully fed.

The larvae of the webbing clothes moth spin a loose silken web or tunnel on the surface of the food material in which to shelter. When they are ready to pupate a silken cocoon is formed, into the walls of which may be woven little pieces

of wool, grass, etc. The caterpillar stage may last from four or five weeks to several months, or even years, under very adverse conditions, so that it is quite impossible to give a definite length to the life cycle of the insect. The pupal stage may last from two to five weeks, after which the adult moths emerge to spend a brief period mating and laying eggs.



Edge of a wool carpet eaten by larvae of the carpet beetle. Note only the woollen pile is eaten, the vegetable fibres of the warp being untouched.
(From U.S. Dept. Agric.)

The larvae of the case-bearing clothes moth differ from the species just described in that the young caterpillars immediately spin themselves a compact covering of closely woven silk and fragments of the material on which they are feeding. The case is gradually enlarged as the insect grows, and the caterpillar lives in this structure throughout its life, and in feeding protudes the head and legs and drags the case about from place to place. When ready to pupate the caterpillar often strays right away from the food material and the small woven cases containing pupae may sometimes be found suspended from the bare walls or ceiling of a room.

Material Attacked.

Cotton and silk goods are not subject to attack by clothes moths, but any fabrics made from wool or fur are very attractive, as are also feathers and made-up furs. Piano felts and felt hats may, of course, be included in the list of potential foods. It has been observed that dirty garments are more readily attacked than clean materials.

CARPET BEETLES.

There are several species of carpet beetles which may be met with in Western Australian homes, but the damage done by all is so similar and their life histories so much alike that the actual species concerned is of little importance.

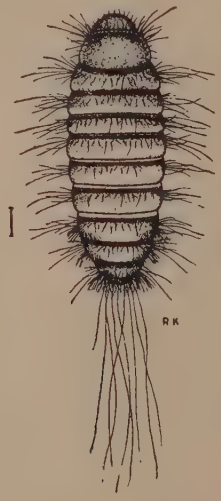
The Australian carpet beetle, *Anthrenocerus australis*, is one of the commonest species and its life history and habits may be regarded as characteristic of the group.

General Description.

The beetle is a small rounded creature, a little over ⅛ of an inch in length. It is dark in colour with four distinct wavy white bands across the body, giving the insect a mottled appearance.

The Australian Carpet Beetle.

The larval or grub stage is the most destructive form of the insect, but is frequently not associated by the housewife with this beetle at all, due to a lack of knowledge of the creature's life history. The tiny grub is provided with legs and is quite active. Its general form, however, is somewhat obscured by a covering of hairs, a long tapering brush being carried at the tail end. The creature may perhaps best be described as looking rather like a miniature woolly bear caterpillar.



Larvae of the Australian Carpet Beetle.

LIFE HISTORY AND HABITS.

The carpet beetle may at times be found in large numbers in the flower garden, for the beetles are attracted by the pollen carried by many flowers Indoors the eggs of the beetle are laid almost anywhere, but preferably on material such as wool, feathers, or fur, which will serve as food for the young.

The eggs hatch in about a fortnight, and the larvae may be active for several months according to weather conditions. As they grow the grubs shed their skins, and these empty hairy skins are one of the characteristic signs of the carpet beetle's presence.

Webbing clothes moth.—Eggs (much enlarged) in upper circle, moths in lower circle, caterpillars and larval shelters on cloth (all somewhat enlarged.
(After Gibson and Twinn.)

Materials Attacked.

Practically any materials made from wool, fur, or other animal products, including silk, are subject to attack. As the name carpet beetle suggests, floor coverings are amongst the commonest goods damaged, but clothing, etc., is also liable to attack.

CONTROL.

Both the clothes moth and the carpet beetle work best in secluded spots. Patches of carpet behind big pieces of furniture such as pianos, sideboards, etc., which are rarely moved, are particularly vulnerable, and of course their liking for woollens which have been stored away for long periods is only too well known to all.

The first essential should be rather the prevention of damage than the control of an outbreak once it has occurred. In this direction it cannot be over-emphasised that the frequent airing, shaking, or beating of carpets, clothing, etc., in the sunshine is of the greatest importance. Where goods must be stored away and left for long periods every care should be taken to see that they are clean and free from beetles at the time of being packed. If they are wrapped in several sheets of sound paper, each sheet being folded so that the joins do not coincide, a practically insect proof container can be formed. The wrapped goods should be packed in a sound trunk and liberally treated with naphthalene or paradichlorobenzene, about 1 lb. being sufficient for a moderate sized trunk. For the storage

of suits, cotton bags are sometimes used. A liberal dressing of naphthalene or paradichlorobenzene should be placed in the bag and especial care is necessary to see that the mouth of the bag is securely fastened.

Case-bearing clothes moth.—Larval cases and work on woollen glove (somewhat enlarged).

(After Gibson and Twinn.)

In the case of carpets and upholstered furniture the frequent use of the vacuum cleaner will prevent any damage, but where injury is actually noticed the liberal use of any proprietary fly spray or even plain kerosene will kill any insects contacted.

The injury to piano felt may be prevented by suspending a bag of fumigant crystals, such as naphthalene, within the instrument and keeping the lid closed.

Upholstered furniture sometimes presents an especial problem on account of the depth at which the insect may be working. Liberal dressings of fumigant flakes pushed down behind the seat may be helpful, also the copious use of fly sprays. In some cases, however, it may be necessary to remove the fabric to effectively reach the insects.

Naphthalene and Paradichlorobenzene. Both these materials are repellent to carpet beetles. The fumes of the latter are released rather more quickly than are those of naphthalene, hence paradichlorobenzene is slightly more effective as a fumigant when it is desired to deal with an attack, but flaked naphthalene lasts longer, and hence gives a longer period of security when packed with clothes or carpets. A mixture of both is sometimes used with good effect.

Kerosene and Kerosene-Pyrethrum Fly Sprays. These ingredients kill only by contact and have little or no repellent action.

Turpentine. This is an effective contact insecticide and leaves a repellent residue for some time, but may stain.

Camphor. In a close-fitting box camphor is effective, but more expensive than naphthalene, etc.

Hot Water. A dipping in hot water (anything over 140 deg. F.) for 10 seconds or more will kill all stages.

Insect-proofing Solution. A number of chemicals have been used with greater or lesser success to insect proof fabrics such as carpets and floor coverings. A simple and effective treatment consists of impregnating the material with sodium

fluosilicate. The powder is dissolved in warm water at the rate of one ounce to the gallon, and the mixture is applied so as to gain as deep a penetration of the fabric as possible.

Cold Storage. Carpet beetles and moths will not work at low temperatures, and so valuable furs, etc., are sometimes kept in cool stores. Care should be taken to see that only clean furs are stored, however, as the grubs may remain dormant for long periods and then commence feeding when the fur is later brought out for use.

Fumigation. Where necessary trunks or even rooms may be fumigated for beetle control, and carbon bisulphide, cyanide, or various proprietary fumigants may be used. Carbon bisulphide is easily used and may be placed in a sealed trunk at the rate of about two tablespoonsful to six cubic feet. The gas, however, is explosive and inflammable, and so should be used out of doors.

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Experiments With Wimmera Rye Grass.

I. Thomas, Superintendent of Wheat Farming.

F. L. Shier, Assistant Superintendent of Wheat Farming.

The increasing sheep numbers in the agricultural areas has served to direct attention to the improvement of pastures, and each year experimental plantings of a wide range of fodder species are made at the Agricultural Research Stations. In the drier districts the dominant species on heavy land following cereals is barley grass and on light land capeweed and brome grasses, with varying proportions of native clovers and trefoils. In the sections of the wheat belt which carry subclover, wild geranium (Erodium spp.) is an important weed. These volunteer species are for the most part inferior as pasture types.

Of the grasses tested, best results, particularly on the heavier soils at both Merredin and Salmon Gums have been given by Wimmera rye grass. On lighter soils capeweed is an aggressive and often successful competitor because of its vigorous early growth. Encouraging results have also been obtained at Merredin on heavy land with Barrel medic, *Medicago tribuloides*, which is more leafy and productive than the common burr trefoils (*M. denticulata and M. spp.*).

At Merredin a number of experiments have been conducted on the establishment and maintenance of Wimmera rye grass, whilst at Salmon Gums the regeneration and maintenance of this pasture have been studied.

THE ORIGIN OF WIMMERA RYE GRASS (*Lolium subulatum*).

This grass first became prominent in the Wimmera district of Victoria and presumably originated from a natural cross between two rye grass species. The hybrid origin of the grass probably accounts for the wide variability in maturity

and growth habit observed in plantings of commercial seed. It is a palatable, nutritious grass, readily eaten by stock in the green or dry condition. Because of its late maturity it remains green after other naturally occurring wheat belt grasses have dried off.

Investigations at Merredin.

In addition to experiments dealing with methods of establishing and maintaining Wimmera rye grass at the Merredin Research Station, selections have also been made which it is hoped will result in the production of superior strains.

RAINFALL—MERREDIN RESEARCH STATION.

Year.	Jan.	Feb.	Mar.	Apr.	Growing Period.							Nov.	Dec.	Total.
					May.	June.	July.	Aug.	Sep.	Oct.	Total.			
1942	46	8	132	106	205	181	169	169	76	40	840	24	317	1,464
1943	59	334	229	274	165	242	171	191	118	26	913	10	43	1,862
Av. 32 years	47	60	100	92	134	188	178	149	82	80	811	42	62	1,214

Methods of Establishment.

Wimmera rye grass is usually established by sowing half to two pounds to the acre with the last crop before leaving a paddock in pasture. This method was tested against others for its effectiveness as a means of establishing the grass. The possibility of the practice resulting in a marked depreciation in the cover crop grain yield was also investigated.

The Effect of Wimmera Rye Grass on a Cover Crop Harvested for Grain.

In this experiment which was conducted in both 1942 and 1943, the wheat cover crop was sown uniformly at 45 lbs. per acre, but the rate of Wimmera rye grass application was varied.

Quantity of Rye Grass.	Noongaar 1942		Bencubbin 1943	
	Grain Yield.		Grain Yield.	
	bus.	lbs.	bus.	lbs.
No rye grass	17	38	28	16
1 lb. rye grass per acre	16	13	28	48
4 lbs. rye grass per acre	15	50	26	56
8 lbs. rye grass per acre	15	36	27	36
Diff. for signif. (P. = ·05)	0	52	No treatment effect.	

In 1942 there was a marked depreciation in the yield of the cover crop due to the rye grass, but in 1943 variations due to soil, etc., were sufficient to account for the observed difference and mask any possible effect of the Wimmera rye grass on the cover crop yields.

Cover Crop Management.

Four methods of establishing a sward of Wimmera rye grass were examined, three with and one (control) without a cover crop. The experiment was sown on

fallow on April 21st, 1942, but germination did not occur until after rain on May 1st. Superphosphate was applied at 60 lbs. per acre.

(i) *Cover Crop Stripped for Grain.*—This series of plots was sown with Wimmera rye grass at 2 lbs. per acre and Bencubbin wheat at 45 lbs. per acre. An excellent crop yielding 8 bags per acre was obtained. In the following year, 1943, the stand of Wimmera rye grass was poor, due apparently to the restricted setting of seed during the previous season. Where the cover crop is a heavy one, the subsequent stand of Wimmera rye grass is usually poor. In view of the possible depression of the grain yield of the cover crop by the rye grass and the poor stands obtained when the cover crop is heavy, other methods of establishing rye grass are to be preferred.

(ii) *Cover Crop Cut for Hay.*—The planting procedure was identical with (i) above and a 30 cwt. per acre crop of hay was cut in late September. Cutting at that growth stage apparently prevented the rye grass from seeding, since a negligible stand was obtained on these plots in 1943.

(iii) *Cereal Cover Crop (Oats) Completely Fed Off.*—This series of plots was sown with 40 lbs. of Wongan oats and 2 lbs. of Wimmera rye grass per acre. The oats were grazed down in July and again in August. From the second grazing the oats failed to recover, but the rye grass developed to a good stand.

Oats and Wimmera rye grass, whether sown on fallow or stubble, constitute an excellent grazing mixture, giving a high level of productivity over the whole growing season. The vigorous early growth of the cereal supplies the winter grazing when the Wimmera makes little bulk and the grass supplies the spring and early summer grazing, remaining green after the naturally occurring grasses have dried off. The experimental plots sown with oats and Wimmera fed off during the winter gave an excellent sward in the following year, equalling that of the control plots sown without a cover crop.

(iv) *Wimmera Rye Grass Without a Cover Crop.*—The juvenile growth of Wimmera rye grass affords little grazing and pure stands are not very productive before the spring. Wimmera rye grass is an aggressive species and it was noticeable that weeds such as double-gees (*Emex australis*) were much less noticeable in good swards of rye grass than on the plots carrying volunteer species and self-sown cereals.

Depth of Planting.

This series of plots was sown on fallow in late April, 1942, and germinated following early May rains. Each plot was sown at 2 lbs. of Wimmera rye grass and 60 lbs. super per acre. Three two-square yard quadrats were cut from each plot and a representative sample dried until moisture free.

Planting Depth.	Yield of Green Material.	Hay Yield. (Dry Matter + 10%.)
	cwts. per acre.	cwts per acre.
Surface (Harrowed in)	103	33
One inch deep	86	27
Two inches deep	66	21
Three inches deep	60	19
Diff. for signif. (P. = ·05)	14	...

In 1943 all plots carried an excellent stand of Wimmera and no differences could be observed from the different seeding depths. Since there is a relationship up to a point between the number of plants and the yield of green material, the above results indicate that shallow planting is desirable and that planting to a similar depth to wheat will depress the yield of Wimmera.

Rate of Seeding.

Sown on fallow on April 21st, this experiment germinated following early May rains. Growth was excellent and grass hay yields of over two tons per acre were obtained.

Rate of Sowing.	Yield of Green Material.	Hay Yield. (Dry matter + 10%.)
	cwts. per acre.	cwts. per acre.
8 lbs. seed per acre	140	41
4 lbs. seed per acre	116	34
2 lbs. seed per acre	99	29
1 lb. seed per acre	66	19
Diff. for signif. (P. = ·05)	21	...

From the above, applications of up to 8 lbs. per acre of seed are obviously profitable when Wimmera is sown as a pure stand on fallow. In 1943 all plots carried a dense sward and no differences were apparent in the several seeding rates.

Time of Planting.

Wimmera rye grass is a slow maturing plant and requires early seeding for effective growth. Four plantings were made in this experiment which was sown with 2 lbs. per acre of seed and 60 lbs. per acre superphosphate on fallow. The April planting did not germinate until after rain on May 1st.

Planting Date.	Green Material.	Hay. (Moisture free + 10%.)
	cwts. per acre.	cwts. per acre.
April 8	62	18
May 8	43	12
June 16	23	7
July 16	½	...
Diff. for signif. (P. = ·05)	8½	...

In 1943 there was a marked difference between the treatments. There was practically no Wimmera at all on the July plots, whilst those of June only carried a poor stand. There was an excellent sward on the April and May plots, somewhat in favour of the former.

Pasture Plant Breeding Rows. Merredin Research Station.

Maintenance of Wimmera Rye Grass.

The maintenance of Wimmera rye grass will depend on satisfactory management, the most important features of which are firstly to allow the grass to seed down and secondly to renovate the soil by scarifying during the early autumn before rain falls.

Experiments dealing with these aspects are long term ones, and results will not be complete for a number of years. However, at Salmon Gums, where the experiments are in the 4th year, it is quite evident that periodic cultivation, say perhaps every 2-4 years, with the scarifier with or without a cover crop is necessary to maintain Wimmera rye grass at a high level of productivity.

Improvement by Selection.

Early maturing strains have been isolated at the Merredin Research Station and the most promising will be tested against the bulk strain. Earlier maturity should make for better persistence, particularly in the drier seasons. Because the

juvenile growth of the early strain is more vigorous than that of the commercial seed, a mixture of the two should give a longer productive season than either alone.

Grateful acknowledgment is made to the managers of the Merredin and Salmon Gums Research Stations, Messrs. J. H. Langfield and F. A. Newman, for their assistance with these experiments.

SUMMARY.

Wimmera rye has proved a useful fodder grass in wheat belt areas of the State.

Experiments have shown that early and shallow planting are desirable. It is unwise to attempt to establish Wimmera in a crop which is to be cut for hay or stripped for grain.

A satisfactory method of establishment is to sow 2-4 lbs. per acre as early as possible on stubble or fallowed land with a cereal cover crop intended to provide autumn or winter grazing.

The sowing of Wimmera rye grass with a crop to be stripped for grain probably results in a small depression in the grain yield.

A fine shallow seed bed is desirable.

Early maturing selections of Wimmera rye grass have shown promise and one has been raised in bulk for more extensive trials.

General experience has shown that cultivation is of material assistance in maintaining stands of Wimmera rye grass.

Pig Feeding Demonstration—Denmark Research Station.

M. Cullity, Superintendent of Dairying,

and

V. E. Randell, Farm Manager.

The urgency for a rapid increase in pig production has been explained repeatedly during the past several months. The target for production in Western Australia was set at approximately 50% more than had ever previously been produced. As a means of reducing this target into terms which every dairy farmer could apply to his own farm, it has been suggested that each should aim at marketing two bacon pigs per cow.

In some quarters there has been a degree of reluctance to expand activities because of the feeling that insufficient skim milk would be available to feed the larger number of pigs.

The usual practice throughout the dairying areas has been to rely on skim milk and grazing, and any accidental forage which may be available for growing pigs to near market weights. At this stage the pigs are "topped off" with a few bushels of pollard which is the food normally used.

Wheat usually has been on hand in this State in large quantities but has been too costly for feeding purposes when purchased in small quantities and while the price of pigs was lower than it is at present.

Since the announcement of the "Pig Plan," by which the Commonwealth Government has guaranteed prices equivalent to 9d. per lb. at treatment works for first quality bacon, and since the commencement of the scheme for the provision of cheap wheat in bags, farmers have become increasingly interested in the possibilities of expansion.

There has been some doubt in the minds of many as to whether they should alter their system of management from one which is merely using the pig as a means of ridding them of a surplus of skim milk, to active pig raising in which by the use of grain the skim milk can be used for a larger number of pigs and so return a greater profit.

In order to give some direct information on the use of wheat with skim milk a small demonstration was carried out at the Denmark Research Station.

The following procedure was adopted:—

Six pigs were selected from a litter which had been grown to light porker weights by using buttermilk. These were the only animals available at the time. They were divided as evenly as possible into two groups and during a fitting period of two weeks were gradually changed from buttermilk to skim milk.

The groups were then fed as follows:—

Group 1.—One gallon skim milk with the addition of a quantity of crushed wheat, commencing with 2½ lbs. per day and increasing by ¼ lb. each week until 5½ lbs. were being fed in the final week.

Group 2.—Skim milk only, commencing with 3½ gallons per day and increasing by ¼ gallon per week until the end of the seventh week when two gallons of skim milk were replaced by 2 lbs. of crushed wheat. In the final week—four weeks late—this group was receiving 4¼ gallons of skim milk and 2 lbs. grain.

It will be noted that the total weight of dry matter fed to each group was approximately the same.

The main details of the trial are given in the following table:—

Table 1.

	Group 1.	Group 2.
Average Weight at the start of the Trial	109·6 lb.	107·6 lb.
Average Weight at the end of the Trial	199·3 lb.	194·6 lb.
Gain—Live weight	89·7 lb.	87·0 lb.
Number of days in Trial	77	77
Gain—Live weight per day	1·16 lb.	1·13 lb.
Wheat consumed	1,009 lb.	180 lb.
Skim milk	86 galls.	1017 galls.
Grain consumed per lb. live weight increase	3·7 lb.	0·7 lb.
Skim milk consumed per lb. live weight increase	0·3 galls.	3·9 galls.
Total food consumed per lb. live weight increase ... ... (1 gallon skim = 1 lb.)	4·0 lb.	4·6 lb.

Table 1 shows the relative rate of increase in the live weights of the two groups. As will be seen, there has been very little difference in the rates of gain.

This was expected as the quantities of dry matter fed to the two groups was approximately the same.

The pigs were forwarded to the bacon factory on the 8th and were slaughtered on the 14th February.

An examination of the carcasses later disclosed that while all carcasses were first grade those topped off appeared to have a slightly larger proportion of meat to fat.

Table 2.

Group.	Live Weight Gain lb.	Dressed Weight Gain lb.	Value at 9d. per lb.	Cost of Wheat.	Profit over Cost of Wheat.		
					Group.	Per Pig.	Per Gallon of Skim Milk.
			£ s. d.	£ s. d.	£ s. d.	£ s. d.	Pence.
1	89·7	67·2	7 11 3	2 16 1	4 15 2	1 11 8	13·3
2	87·0	65·2	7 6 9	10 0	6 16 9	2 5 7	1·6

Dressed weight gain assumed as 75% of live weight gain.

Table 2 gives details of the value of the two groups—the cost of grain for each and the profit over the cost of grain per group and per gallon of skim milk consumed. It will be noted that the group which received wheat in addition to skim milk showed 13s. 11d. less profit for each pig, but the return for each gallon of skim milk consumed was eight times as great where wheat was used regularly.

It has been shown that a profit of £6 16s. 9d. only was obtained from feeding 1017 gallons, while £4 15s. 2d. was obtained from 86 gallons.

If the 1017 gallons had been fed in conjunction with wheat as for Group 1, a profit of £53 16s. over the cost of wheat would have been obtained.

It is clear from the foregoing that there is tremendous scope for a great increase in pig raising among dairy farmers by changing the normal practice of "topping off" to one where wheat is used as a regular supplement to the skim milk. In this way more pigs can be fed and a much greater total profit be obtained.

However, some increase can be achieved in this way by all farmers. By feeding more pigs they will make more profit for themselves and assist in achieving the target which has been set.

It is unlikely that they would be able to increase the number of pigs grown by the ratio of 8:1 as indicated in the foregoing details, as a number of other factors, such as the supply of breeding animals, the difficulty of carrying a large number of pigs satisfactorily during the summer months when skim milk supplies are at their lowest ebb, would interfere. However some increase can be achieved in this way by all farmers. By feeding more pigs they will make more profit for themselves and assist in achieving the target which has been set.

Oat Variety Trials.

I. Thomas (Superintendent of Wheat Farming).
A. J. Millington (Field Technician).

Trials with oats were conducted on five wheat belt Research Stations to obtain data on the relative productivity of the leading varieties, firstly for grain only and secondly for grazing and recovery.

Grain Yield Trials.

The relative grain yielding ability of the different varieties was determined by trials sown on fallow. The layout was such that each variety was harvested as soon as it matured.

Grazing and Recovery Trials.

Cereal crops are frequently fed down in the juvenile stages either to check excessive growth or to provide early grazing for livestock, particularly lambing ewes. There is an increasing tendency, with the extension of the fat lamb industry, to make provision for early winter feed by planting either oats or barley, varieties of which vary greatly in their suitability for the purpose. The grazing may be restricted so that recovery for grain follows, or the cereals may be grazed continuously until they are exhausted as a source of fodder.

Management of Cereals for Grazing and Recovery.

Crops for green feed are sown as early as considerations of weed control permit, either on ploughed up stubble or as in the case of these experiments, on fallow. Varieties differ notably in the length of their different growth stages and where recovery to yield grain is desired, careful attention must be paid to the management of the grazed crop. Just how late in the season grazing is permissible will be determined partly by the district and its rainfall and partly by the variety. It is not advisable to graze varieties after they begin to "shoot" into ear since by removing the growing points and embryonic ears, grain yields are very much depressed. An indication of the behaviour of a typical general purpose variety under grazing is given by data obtained by Mr. E. Langfield with the variety Wongan at the Merredin Research Station in 1942. Four different plots were cut at fortnightly intervals from the end of June when the crop was 6in. high until it matured in October. After cutting each plot was allowed to mature so that their grain yields represent the recovery after cutting. The later the plots were cut, the lower the subsequent grain yield until from those cut back in September there was practically no recovery. The grain yield from the plots which were not cut back, was 17.7 bushels per acre, so that one cutting at the end of June resulted in the subsequent grain yield being depressed by 3.4 bushels per acre.

Whilst the grain yields, from plots cut up to the end of July were fairly well maintained, there was a marked reduction in the recovery made by plants cut back after that period. The end of July was a critical date from the viewpoint of grazing and recovery as it marked the commencement of "shooting" when the crop began to run into ear. Since for experimental purposes, cutting is equivalent to grazing, crops from which it is intended to strip grain should not be grazed after "shooting" has commenced.

With Fulghum, "shooting" commences later in the season than with the general purpose varieties and consequently it can be grazed longer without seriously diminishing the subsequent grain yield.

TABLE 1.

OAT VARIETY TRIALS (GRAIN ONLY), 1943.

Variety.	WONGAN HILLS RESEARCH STATION				MERREDIN RESEARCH STATION.				SALMON GUMS RESEARCH STATION.			
	Average Plot Yield.		Guyra Control.		Average P.o. Yie'd.		Guyra Control.		Average Plot Yield.		Guyra Control.	
	Varietal.	Guyra Control.	1943.	1941-3.	Varietal.	Guyra Control.	1943.	1941-3.	Varietal.	Guyra Control.	1943.	1942-3.
	bus. lbs.	bus. lb.	%	%	bus. lb.	bus. lb.	%	%	bus. lb.	bus. lb.	%	%
Mulga	24 12	19 12	126	104	37 32	30 8	125	113	26 10	26 3	101	75
Dale	22 24	19 20	116	101	....	....	....	....	24 16	27 24	88	87
Ballidu	28 1	19 12	146	128	40 16	30 8	133	131	27 2	29 11	98	99
Wongan	23 36	18 8	132	97	25 0	27 4	92	103	....	....	....	....
Algerian	20 8	19 20	103	103	....	....	....	....	....	....	....	....
M. 59	15 16	18 8	85	....	....	....	....	....	21 26	26 3	83	....

Table 2.

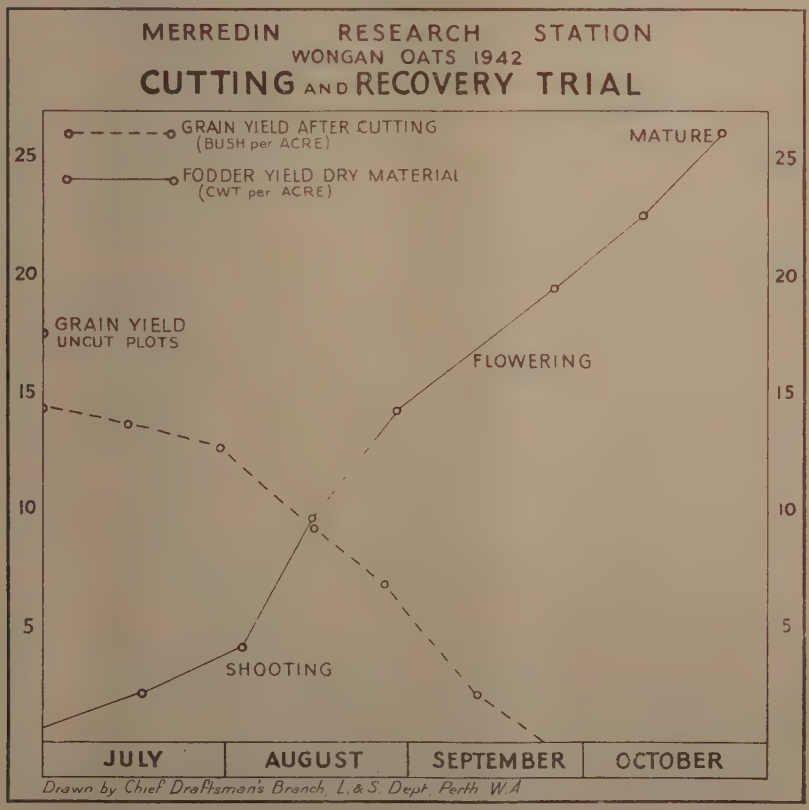
MERREDIN RESEARCH STATION.

OAT RECOVERY EXPERIMENT, 1942.

Variety: *WONGAN*.

Cutting Date.	Moisture Free Material.	Grain Yield on plots after cutting back.
	cwt. per acre.	bus. per acre.
June 30	0·6	14·3
July 17	2·1	13·7
July 30	4·1	12·6
August 13	9·5	9·1
August 27	14·2	6·7
September 10	...*	2·9
September 24	19·3	*Nil*
October 8	22·4	*Nil*
October 21	26·2	*Nil*
Diff. for signif. (P. = ·05)	1·5	2·2

* Discarded owing to inaccurate moisture determination.



Procedure.

Due to adverse weather conditions, the planting date, May 3rd, was later than had been desired at Merredin. The Avondale experiment was sown on March 31st and the Chapman plots on April 16th.

Quadrats were cut from each plot at the Merredin and Avondale Research Stations to ascertain the green feed yield, after which they were grazed to a uniform level by sheep. Two grazings were made at the Avondale and one at the Merredin and Chapman Research Stations. At the latter station, the grazing yields were not taken. When mature, the plots were harvested with normal farm machinery to ascertain the grain yields.

At the Avondale Research Station, Atlas barley was included to give a comparison between a six-row barley and oats for grazing and recovery.

VARIETIES.

Late Maturing.

Algerian, the standard late maturing oat variety, possesses medium strong straw and is suitable for grazing and recovery in the wetter districts.

Mid-season Maturing.

Guyra is notable for its plump grain but is very weak strawed and frequently lodges. Although a fairly good hay variety, the straw tends to be very coarse under favourable conditions of growth. Guyra is an indifferent variety for grazing and recovery since the early growth is relatively sparse and the subsequent grain yields only fair.

Fulghum is notable for the length of its leafy growth phase prior to "shooting" into ear. This enables it to be grazed later in the season than the general purpose variety Dale. It is not as vigorous in the early stages as Dale but it is, however, a very suitable variety for late winter or early spring feed.

The straw strength of Fulghum, particularly when ungrazed, is very poor and it is for this reason not a good general purpose variety.

Dale, which was bred at the Wongan Hills Research Station, has given satisfactory results as a general purpose variety. It is superior to Guyra in straw strength and also as a variety for grazing and recovery.

Early Maturing.

Mulga is the most widely grown early maturing variety, but it is weak strawed and frequently lodges. Although a satisfactory hay oat, the early growth of Mulga is sparse and the recovery is inferior to that of Ballidu. Mulga is also very sensitive to over grazing in the juvenile stages and has given the lowest yields of the varieties tested for grazing and recovery.

Ballidu has demonstrated its general superiority to Mulga in trials on Research Stations and is proving satisfactory on growers' holdings. The straw strength and grain yields are outstanding among early maturing varieties, whilst its leafy early growth and vigorous recovery make it suitable for grazing and recovery. Ballidu and Dale were bred at the Wongan Hills Research Station by Mr. D. R. Bateman and released to farmers in 1943.

TABLE 3.

GRAZING AND RECOVERY TRIALS.

Variety.	Avondale—Planted 31st March.						Merredin.		Chapman.	
	Dry Matter Yield.				Grain Yield.		Dry Matter Yield.	Grain Yield.	Grain Yield per Acre.	
	10·6 (1st Cut).	7·7 (2nd Cut).	Total.	Average Total. 1941–43.	1943.	1941–43 Average.	Cut, 5–7–43.	bus. per Acre.	Early Planted Varieties.	Late Planted Varieties.
	cwt. per acre.	cwt. per acre.	cwt. per acre.	cwt. per acre.	bus.	bus.	cwt. per acre.		bus. lb.	bus. lb.
Dale	14·5	4·2	18·7	18·5	29·5	21·7	...	...	37 2	...
Fulghum	13·5	5·6	19·1	18·1	22·6	19·1	3·2	20·5	24 17	...
Ballidu	11·5†	3·8	15·3	17·4	29·5	23·0	4·5	19·5	35 0	...
Mulga	...	...	...	...	...	...	4·7	16·2	...	24 10
Guyra	13·6	3·9	17·5	...	22·1	...	...	...	...	...
M59	...	...	...	...	...	...	5·9	11·2	...	15 17
Wongan	...	...	...	...	...	...	5·1	15·5	...	24 19
Atlas	17·1	6·0	23·1	...	14·2*	...	...	...	...	...
Difference for significance (P = ·05)	2·0	0·5	2·3	...	3·6	...	0·8	2·6	8 6	8 0

* 50 lbs. per bushel. † Poor germination in 1943 gave a thin stand.

Very Early Maturing.

Wongan was the first of the improved oat varieties to be released by the Department and it is notable for its vigorous early growth and strong straw. Satisfactory as a hay variety it tends to shed grain if left unharvested after it is mature. Because of the vigorous juvenile growth, Wongan is suitable for early winter feed but it cannot be grazed without serious damage quite as late in the season as can Ballidu.

M. 59 (Mulga x Laggan).—Earlier maturing than Wongan, M. 59 proved too weak strawed to have commercial application.

Atlas Barley.

The results of trials with this typical six-row barley indicate that it is superior to oats as a source of early green feed, particularly at the time of the first grazing. This barley variety is very susceptible, particularly in the wetter seasons after it has been grazed, to attack by the fungus, powdery mildew. The recovery is thus often adversely affected. Since oats are not susceptible to powdery mildew, they are preferred for grazing and recovery in the wetter districts. Sheep usually find young oats more palatable than barley.

In the tabulated results, the grain yields of Atlas are given in 50 pound bushels whilst those of the oat varieties in 40 pound bushels. The food value pound for pound is higher for barley than oats and when the grain yields after grazing are considered in terms of feed equivalent per acre, Atlas compares favourably with the most prolific oat varieties.

OAT VARIETY TRIALS ON RESEARCH STATIONS.

Summary.—Oat varieties were tested for grain yield with and without grazing.

Grazing trials were conducted to test the suitability of the various varieties for grazing and recovery.

Grazing after "shooting" commences will markedly reduce grain yields.

The following are recommended varieties:—

Very early maturing—"Wongan."
Earl maturing—"Ballidu."
Midseason maturing—"Dale," "Guyra," "Fulghum" (for grazing only).
Late—"Algerian."

ACKNOWLEDGMENT.

Grateful acknowledgment is made to the managers of the Research Stations as the officers responsible for the field work associated with the above experiments:—

Avondale Research Station—Mr. W. A. Human.
Chapman Research Station—Mr. F. Gishubl.
Merredin Research Station—Mr. J. H. Langfield.
Salmon Gums Research Station—Mr. F. A. Newman.
Wongan Hills Research Station—Mr. D. R. Bateman.

Feeding Dairy Herds for Production.

M. Cullity, Superintendent of Dairying.

The farmers of Australia have responded to the call for the production of more food by providing more of every kind with the exception of dairy produce. With dairying the problem of obtaining higher yields has been most difficult, due to the acute manpower shortage and also largely to the attractive prices which were offered for other commodities in the early war years. As a result, the amounts of dairy produce available each year have been lower than in pre-war years.

While this decline has occurred, the demand for all types of dairy produce for export from Australia to Britain has risen, due to the loss of supplies from Europe, principally Denmark. Greater demands are also being made from inside Australia because of the large body of troops which are now based on this country.

To encourage production and maintain supplies the contract system was developed by the British and Commonwealth Governments. More recently the Commonwealth Government has offered a substantial subsidy. The moves have had the effect of stablilising and increasing prices. Nevertheless the supply has been insufficient and rationing was necessary in order to allow the conservation of larger quantities for export to Britain.

In this State, the position is not as described for Australia as a whole. If 1939/40 is taken as the normal year, output in each year since of butter, cheese and condensed milk calculated as butterfat has been greater, as shown hereunder:—

1939/40	100
1940/41	101.4
1941/42	114.2
1942/43	107.6

Despite this improvement still better results are possible and an effort is required from all to lift production as much as possible.

The Target for Production.

In order to give farmers something to aim at, goals or targets have been determined for each State. Those adopted for Western Australia are 7,200 tons of butter and 700 tons of cheese. It is estimated that the output of butter during the current year will be about 1,000,000 lbs. below the target. If the same goal is set for 1944/45, it is believed that the increase can be obtained by better feeding during the autumn and winter.

If the whole increase were to be obtained during the period, May to December, and it is assumed that the produce of only 100,000 of the 130,000 cows in the State is used for manufacturing purposes, an increase of 10 lbs. of butter per cow would be needed. This is 1¼ lbs. of butter per month per cow.

There is no doubt at all that this increase is possible. Actually it is ridiculously small, but the difficulty lies in getting every dairy farmer to plan so that the yield of his cows may be improved.

Trend of Production in Recent Years.

During the last 10 years there has been a rise of approximately 80 per cent. in the amount of butter manufactured. The quantities of cheese and condensed milk have increased by more than 600 and 400 per cent. respectively.

While this large increase has occurred the quantity manufactured during the summer months has not risen. The whole of the higher output has occurred during the months May to December inclusive.

It is interesting to keep this in mind when surveying the possibilities of stimulating still higher production. Further it is valuable to inquire why the higher yields have been obtained only during eight months of the year. The reasons may be put briefly as follows:—

Reasons for Greater Output in Winter and Spring.

The output of butter is influenced directly by the amount of feed which is available for the dairy cattle at any time and maximum production is obtained by arranging the calving of the cows so that they will be in their flush of milk when adequate supplies of paddock feed are available. In this way the feeding of the herd is most economical: conversely when it is necessary to feed dairy cows for production during the summer months, it is found that except under irrigated pasture conditions it is necessary to use large reserves of fodder and to add appreciable amounts of concentrates. Besides making this added call for hand-feeding and so depleting the reserves which are available for use in the autumn and early winter, further labour is required in order to provide and prepare this feed.

It is suggested that dairy farmers should study these facts, and make plans to have ample supplies of hay, silage and concentrates for full feeding of their cows, particularly during the autumn and winter.

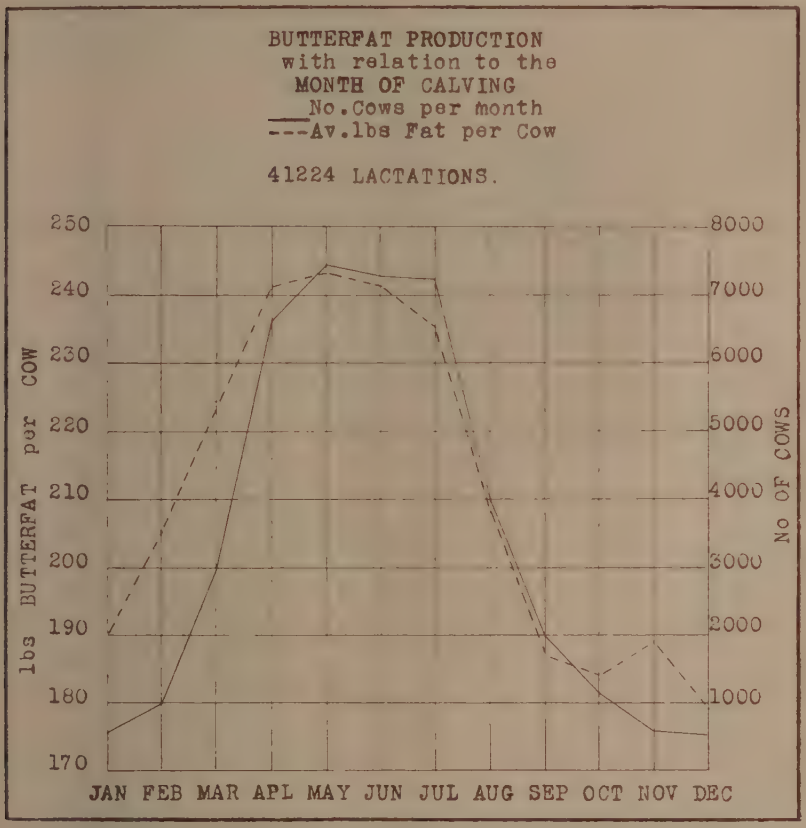
Effect of Early Calving.

In order to be able to exploit the reserves of feed which may be on hand, it is necessary to have the cows in milk at a time when maximum yields may be procured. It has been shown by the analysis of records of grade herd recording that the best performances have been obtained from the cows which calve between the end of March and the end of July.

The information obtained from lactations in the years 1936 to 1942 is summarised in the following table:—

Month.	lbs. Butter-fat	Month	lbs. Butter-fat.
January	190	July	235
February	205	August	209
March	223	September	187
April	241	October	184
May	243	November	189
June	241	December	179

This information is shown graphically in the accompanying figure.



Number of cows calving each month:—

January	585	July	7230
February	1003	August	4044
March	2965	September	1990
April	6592	October	1133
May	7413	November	599
June	7254	December	416

It is clear that the cows which calve in March-July have a much greater chance of continuing in milk for a full lactation period than those which calve in September-October. The latter are in milk only 2-3 months when the summer conditions—except in the irrigation areas—render feeding for milk production difficult. Those calving before the end of July have completed from 5 to 9 months of their lactation before this period.

The data from grade herd recording confirms this inasmuch as by far the greatest proportion of the cows which completed a full 273 day test period calved in April, May, June or July.

Need for Ample feed in Autumn for Early Calving Cows.

It is not enough to be successful in arranging for early calving, it is necessary that the animals be as well fed as they would be in a normal spring period before

full production can be obtained. This feeding should commence some time before the cow calves. Her capacity to produce milk is limited by the development of the udder and this in turn is limited by the amount of nutrients which are available in the body for the purpose.

Before the cow calves, the feed she eats is used for three purposes, to maintain her body, allow proper growth of the calf and to develop her udder. In order to be sure she is getting sufficient food for all these purposes, the best guide the farmer has is to observe whether the animal is gaining in condition. If this is so he may be sure her bodily requirements as well as the needs of the developing calf and udder are catered for and that the improvement in condition is a sign that there is a slight surplus. Any gain in condition at this period should be welcomed as it has been proved that surplus condition at calving is frequently "milked off" and is reflected in a higher fat test in the milk for some months before calving.

After calving feeding should be liberal. Reliance should not be placed on the scanty pasture grazing which usually is available at this time. This is not sufficient for a cow in full milk and if it is not fully supplemented the cows will lose condition quickly and their milk flow will decline. It is a well accepted fact that once a cow's milk has been allowed to fall it is useless trying to revive it by improved feeding. Full rations are needed all the time to maintain a heavy milk flow.

The only safe way to ensure that sufficient fodder is available is by conservation of surplus pasture growth as silage or hay from the previous flush period. The following table gives a comparison between the results following the feeding of hay and those obtained from farms where reliance was placed on the early starting of winter pastures by irrigation in March.

AVERAGE YIELD OF COWS CALVING IN MAY AND JUNE, 1939.*

	May Calvings.		June Calvings.	
	Cows.	Lbs. Butter-fat.	Cows.	Lbs. Butter-fat.
Hay available	43	265	30	269
No hay	64	214	51	237

*Brunswick district.

Other Advantages of Making Ample Conservation of Fodder.

In addition to the prime objective of having reserves for feeding when paddock feed is insufficient there are two other ways in which conservation of fodder for use in the autumn and winter directly assists production:—

(i) The provision of adequate quantities of conserved fodder satisfies the appetite of the cows and so lessens the call made on the germinating pastures and before proper establishment of the new plants can occur. It is an established maxim in the management of annual pastures that they should not be grazed for some weeks after germination if satisfactory growth is desired during the remainder of the autumn and winter. On the greater number of properties this is not possible because the reserves of hay and silage are insufficient to allow feeding on a scale which will satisfy the cows; consequently, grazing must be continued with the result that the new plants can make neither sufficient top nor

root growth and are thereby handicapped for the rest of the season and more particularly during the month of July when feed is usually so scarce that the majority of dairy cows lose condition.

(ii) The position outlined in the preceding paragraph also bears a very direct relationship to the amount of surplus herbage which will be available for conservation in the following spring. Actually it works out in practice that large reserves of fodder usually render larger reserves possible in the succeeding season if normal and sufficient labour and equipment be available for the harvest; where the additional quantity is not conserved increased carrying capacity is available. In either case the conservation of large quantities facilitates the achievement of higher output from the farm, either by larger yields per cow or by increased carrying capacity.

The Use of Concentrates for Promoting Higher Yields.

Generally speaking there is a tendency for farmers to use proportionately greater quantities of concentrates in the summer months than during the winter and spring. However, there is ample scope for lifting production by feeding grain during the latter months. Oats and wheat could be utilised for this purpose.

An excellent example of what is possible came to notice recently. A farmer was in severe financial difficulties and the production of his herd was poor. He was persuaded to use concentrates and financial assistance was made available for their purchase. The use of the grain gave a higher yield and allowed greater conservation of fodder, thus altering the outlook for this man. The following table shows how quickly an increase was achieved.

Year.	Number of Cows.	Yield Butter-fat lbs.	
		Per Cow.	Total.
1940–41	22	175	3,850
1941–42	24	128	3,105
1942–43	25	255	6,383

With the present prices of wheat and butterfat, it pays well to feed cows with grain liberally, particularly during the autumn and winter months when the protein content of the young pasture growth is high.

Recent experiments and calculations made in Iowa, U.S.A., provide a ready means for the farmer to calculate when it is profitable to use supplementary grain mixtures for feeding his herd.

The costs of feeding and the value of added yield with increased rations were compared and it was shown that a balanced grain mixture could be used with profit if 100 lbs. of the mixture did not cost more than 3½ times the value of the butterfat plus the value of 100 lbs. of hay. If this formula is applied to values of 1s. 9d. per lb. butterfat, and £5 per ton hay, it is calculated that 3½ times butterfat value is 73½d. and that of 100 lbs. of hay is 53½d. and the sum is 10s. 7d. It follows therefore that it is profitable to feed grain if its price does not exceed 10s. 7d. per 100 lbs., which is equivalent to 6s. 4d. per 60 lbs. As the highest price at which whole wheat can be bought at any siding is approximately 3s. 8¼d. per bushel and as stock meal (crushed wheat) can be purchased from flour mills at approximately 4s. 4d. per 60 lbs., it follows that there is an ample margin for profit.

Bran and pollard when available are particularly cheap feeds, but unfortunately despite increased production there is insufficient of these products to meet the current demands. Farmers are recommended to use crushed wheat in order to make their purchases of bran and pollard go further.

Wheatmeal can be used in reasonably large quantities without any of the troubles which many farmers attribute to it. As it contains a proportion of fine floury material it is advisable not to feed large quantities alone. It should be mixed throughout any bulky feed, such as chaff or crushed oats, which may be available. Caution, however, should be exercised in introducing this crushed grain to cows: sudden changes of food are liable to upset the digestion and for this reason it is advisable to mix wheatmeal with the other concentrates being fed and to effect gradually a change to larger quantities of wheat. In the summer months it would be useful to add a proportion of a protein-rich concentrate in order to offset the decline in the protein content of any pasture which is then available. Where irrigated pasture is available this is not so necessary.

Conclusion.

From the foregoing the main point emerges as an appeal to farmers to increase the output of milk or cream from their farms.

In order to achieve some success they are recommended to arrange for their herds to calve between the end of March and the end of July as it has been shown that the best yields are obtained from cows calving in those months.

Maximum production, even from early-calving cows, can only be obtained if they are liberally fed on hay and grain. Ample supplies of hay can be assured only if proper control of grazing is exercised, allowing as many paddocks as possible to be shut up for cutting. Ample quantities of wheat are available and this grain can be used very effectively in giving higher yields.

Wheat Variety Trials.

I. THOMAS (Superintendent of Wheat Farming).

A. J. MILLINGTON (Field Technician).

Advantage is taken each year of the five widely dispersed Research Stations, to test new and established varieties under a range of soil and climatic conditions. These are supplemented whenever possible with trials on private holdings.

Although there was an absence of finishing rains, the 1943 season was on the whole favourable, resulting in satisfactory yields except where rust damage was encountered. This disease was present at the Merredin Research Station but caused little damage in these particular trials. Some damage was done by rust at the Wongan Hills and Chapman Research Stations whilst at Mr. K. Williams, Northampton, severe reductions in yield occurred.

Because of the dry finish to the season and their tendency to escape rust injury, the early and very early varieties yielded relatively better than did the midseason ones. Two plantings were made at each Station, the midseason varieties being sown in early May and the early varieties in late May.

In the details of the individual varieties which follow, the flour strength is compared with the State f.a.q. wheat sample. Such comparison is given in general terms because the strength of any particular sample depends on district, soil and seasonal conditions.

Very Early Maturing Varieties.

Bungulla.—This variety is now on an average, the most prolific at three of the five Research Stations. Because of its early maturity it suffered relatively little damage from rust in most localities this season. Plantings of this variety should be made during the third or fourth week in May. The flour strength of Bungulla is generally approximately equal to that of the average f.a.q. wheat of the State.

Noongaar.—Earlier maturing weaker strawed and rather less productive than Bungulla. Noongaar is also moderately susceptible to flag smut. Because the flour strength is generally inferior to that of the f.a.q. standard, Noongaar is no longer distributed by the Department to farmers as pedigree seed.

Early Maturing Varieties.

Koorda.—A relatively recent release by the W.A. Department of Agriculture, Koorda has yielded well on the lighter soils where its strong straw is of great value. Practically immune to flag smut, it tends to be rust escaping in all but the heaviest epidemics. It is more prolific than Merredin, a variety which it was bred to replace.

The flour strength of Koorda is usually about the same as that of the f.a.q. standard.

Eureka I.—Bred at Glen Innes Experiment Farm, New South Wales, as a rust resistant variety, Eureka I. sheds too freely to have wide acceptance. A new strain of rust has appeared in New South Wales which attacks Eureka, but it has not been recorded as yet in Western Australia. The flour strength of Eureka I. is definitely above f.a.q. and some samples approach premium quality.

M. 60 (*Sword* x *Kenya C6041*).—Developed at the Merredin Research Station by Mr. E. Langfield, M. 60 is stout strawed, with a tendency under favourable conditions to be tall growing. In tests conducted by Dr. I. A. Watson at the Sydney University, M. 60 was resistant to the new Eureka-attacking rust strain. Trials in rust infected districts have shown that it is resistant to the rust strains so far recorded in Western Australia. M. 60 will be further tested during the coming season.

Midseason Varieties.

Kondut.—Bred at the Wongan Hills Light Lands Research Station, Kondut has given satisfactory yields over a wide range of soil and climatic conditions.

Although not a rust resistant variety it has given under epidemic conditions this season, much better yields than Bencubbin and Nabawa. It is a stout strawed variety recommended for early planting, particularly on light land and in rust liable districts.

Kondut promises to be a very useful variety, since, not only is it prolific, but in general, the flour strength is superior to that of the f.a.q.

Warigo.—Although the yields from this variety have been disappointing, Warigo is likely to have considerable value as a parent variety since it is resistant to bunt and loose smut as well as rust.

The tests of the flour strength of this variety have given variable results, but it is certainly not inferior to the f.a.q. in this respect.

Eureka II.—Since the new strain of rust capable of attacking this variety has not yet appeared in Western Australia, this variety remains one of the most resistant under test. In appearance and general characteristics, it is very similar to the Dundee parent. Seed supplies of Eureka are being built up with a view to releasing it to farmers, should it remain resistant to rust under West Australian conditions. Flour from Eureka II. is usually well above f.a.q. strength.

The advantage of resistant varieties is illustrated by the results of a trial conducted by the District Adviser, Mr. N. Davenport, at the property of Mr. K. Williams, Northampton, where in 1942 no rust was present and in 1943 a moderate epidemic occurred. The reduction in the yield of Eureka II. in the latter season was due to a combination of soil and seasonal factors and not to rust. These will operate in the case of the other varieties also, but the major reduction in their yields is due to rust. Bencubbin suffered the greatest reduction in yield whilst Kondut was the most prolific of the susceptible varieties under epidemic conditions.

TRIAL AT K. WILLIAMS, NORTHAMPTON.

Variety.	1942: No rust.		1943: Moderate Rust.		Reduction 1943 Yields. (All causes.)
	Yield.	Control.	Yield.	Control.	
	bus. lbs.	%	bus. lbs.	%	bus. lbs.
Fedweb	26 19	90	17 30	107	8 49
Nabawa (Control) ...	29 20	100	16 26	100	12 54
Kondut	31 31	107	18 40	114	12 51
Bencubbin	31 47	108	15 52	97	15 55
Nabawa (Control) ...	29 25	100	16 30	100	12 55
Eureka II	33 47	115	29 36	180	4 11

Late Midseason Maturing.

Fedweb.—The variety Fedweb has been available as pedigree seed since 1939. Although it is fairly resistant to rust, it is too late maturing to have wide acceptance as a variety.

The flour strength of Fedweb is well above that of the common f.a.q. varieties and some samples may approach premium quality.

Recommended Wheat Varieties in Order of Preference.

Very early maturing—Bungulla.
Early Maturing—Koorda.
Midseason maturing—(Bencubbin and Kondut) Nabawa, Ford.
Late maturing—Sutton.
Premium variety—Pusa IV.

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Grateful acknowledgment is made to the managers of the research stations as the officers responsible for the field work associated with the above experiments:—

Avondale Research Station—Mr. W. A. Human.
Chapman Research Station—Mr. F. Gishubl.
Merredin Research Station—Mr. J. H. Langfield.
Salmon Gums Research Station—Mr. F. A. Newman.
Wongan Hills Research Station—Mr. D. R. Bateman.

WHEAT VARIETY TRIALS CONDUCTED ON RESEARCH STATIONS IN 1943

Variety.	CHAPMAN RESEARCH STATION.				AVONDALE RESEARCH STATION.				SALMON GUMS RESEARCH STATION.			
	1943 Season.			Average Percentage over Period (Years in brackets).	1943 Season.			Average Percentage over Period (Years in brackets).	1943 Season.			Average Percentage over Period (Years in brackets).
	Varietal Yield per Acre.	Yield adjacent Nabawa Control.	Percentage of Control.		Varietal Yield per Acre.	Yield adjacent Bencubbin Control.	Percentage of Control.		Varietal Yield per Acre.	Yield adjacent Nabawa Control.	Percentage of Control.	
Very Early Maturing—	bus. lbs.	bus. lbs.	%	%	bus. lbs.	bus. lbs.	%	%	bus. lbs.	bus. lbs.	%	%
Noongaar	....	....	....	....	....	....	....	....	17 33	14 40	119	100 (2)
Bungulla	14 37	9 46	150	118 (5)	24 19	21 30	113	105 (3)	16 48	14 40	114	108 (4)
Early Maturing—												
Eureka I.	12 51	9 46	131	111 (3)	....	....	....	....	....	....	....	....
Gluyas Early	11 25	10 0	114	....	....	....	....	....	15 50	13 39	115	103 (3)
Koorda	11 23	9 20	122	110 (6)	21 42	21 17	102	88 (3)	17 49	13 39	130	114 (4)
Merredin	10 56	9 20	117	100 (5)	19 51	21 17	93	93 (3)	....	....	....	....
M60	13 26	10 0	134	....	22 53	21 30	106	....	....	....	....	....
Midseason Maturing												
Bencubbin	9 2	9 14	98	115 (7)		Control Variety			15 38	15 50	98	105 (4)
Eureka II.	11 28	10 6	113	109 (3)	....	....	....	....	....	....	....	....
Ford	13 6	10 6	130	105 (7)	27 34	27 2	102	97 (2)	19 31	16 54	115	102 (3)
Kondut	12 20	9 14	134	109 (6)	29 17	27 2	109	99 (3)	16 36	15 50	105	92 (4)
Nabawa		Control Variety			....	....	....	....		Control Variety		
Warigo	9 36	9 54	97	101 (2)	24 13	26 27	91	....	....	....	....	....
Late Midseason—												
Fedweb	9 26	9 54	95	103 (6)	18 27	26 27	70	74 (3)	17 4	16 54	101	98 (4)

WHEAT VARIETY TRIALS ON RESEARCH STATIONS IN 1943 (*Continued*).

Variety.	MERREDIN RESEARCH STATION.				WONGAN HILLS RESEARCH STATION.			
	1943 Season.			Average Percentage Over Period (Years in Brackets.)	1943 Season.			Average Percentage Over Period (Years in Brackets.)
	Variety Yield per acre.	Yield Adjacent Bencubbin Control.	Percentage of Control.		Variety Yield per acre.	Yield Adjacent Bencubbin Control.	Percentage of Control.	
	bus. lb.	bus. lb.	%	%	bus. lb.	bus. lb.	%	%
Very Early—								
Bungulla	28 48	27 12	106	96 (3)	20 37	14 53	138	113 (3)
Noongaar	24 48	27 12	91	92 (3)	....	....	....	....
Early Maturing—								
Koorda	23 28	28 24	82	81 (3)	21 4	16 51	125	101 (3)
Merredin	....	....	....	....	19 4	16 51	113	90 (3)
M. 60	24 16	28 24	86	....	20 56	14 53	140	....
Midseason Maturing—								
Fedweb	....	....	....	....	12 16	10 24	117	94 (2)
Kondut	28 32	30 40	93	92 (3)	13 52	10 24	133	112 (2)
Warigo	21 44	30 40	71	....	....	....	....	....

Agricultural Broadcasts.

The following programme of Agricultural Talks has been arranged for the April-June quarter and will be broadcast from Stations 6WF and Regionals at 9.15 p.m. each Thursday.

Date.	Talk Prepared by :	Title.	Summary.
	1.—FARMERS IN A CHANGING WORLD.		
April 6	C. F. H. Jenkins, Government Entomologist, Department of Agriculture	Biological Control or Bug *versus* Bug	A brief account will be given of the principle underlying Biological Control. Some outstanding successes in controlling noxious insects by parasites will be cited and the importance of biological control in relation to the general balance of nature will be stressed.
May 4	G. R. W. Meadly, Assistant Government Botanist, Department of Agriculture	The Role of Seeds in Agriculture	The part played by seeds in present day agriculture will be discussed and the methods of seed testing outlined.
June 1	J. O'Donnell, Forests Department	Forestry and the Farmer	The value of forestry to the Agricultural community will be discussed and means indicated by which adequate timber supplies for farmers' requirements may be assured.
June 29	P. H. Harper, Chairman W.A. State Committee, Council for Scientific and Industrial Research	Science and the Farmer	The value of scientific research to the farming community will be outlined with particular reference to local problems.
	2.—TOPICAL ITEMS.		
April 13 May 11 June 8	G. K. Baron Hay, Under Secretary for Agriculture, will discuss current events in agriculture		
	3.—FARMERS' FORUM.		
April 20 May 18 June 15	Discussion on topics submitted by farmers is arranged by G. A. Currie, Professor of Agriculture, University of Western Australia		
	4.—TECHNICAL TALKS.		
April 27	A. J. Millington, Department of Agriculture	Objectives in flax and Cereal Breeding in W.A.	The aims of the plant breeder and progress so far achieved will be discussed.
May 25	M. Cullity, Superintendent of Dairying, Department of Agriculture	Feeding and Management	How liberal feeding and improved management can result in increased dairy production.
June 22	C. F. H. Jenkins, Government Entomologist, Department of Agriculture	Grasshoppers and Locusts	The importance of grass hoppers and locusts to agriculture will be outlined and the control measures against the principal local species described.

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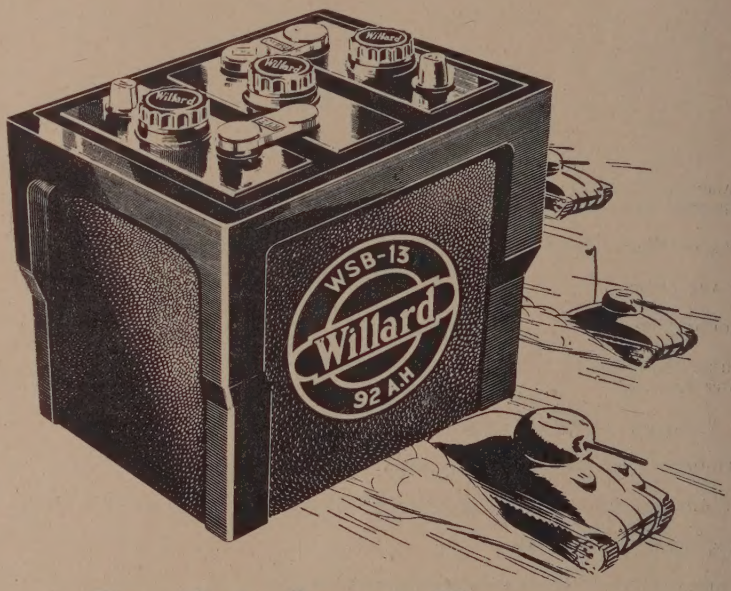

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